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TOPOGRAPHIC AND GEOLOGIC SURVEY
OF PENNSYLVANIA

REPORT No. 4

THE MINERAL PIGMENTS OF PENNSYLVANIA

BY
BENJAMIN L. MILLER

HARRISBURG:
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CHAPTER I.

INTRODUCTION.

In the Spring of 1909 the U. S. Geological Survey authorized J. C. Stoddard, A. C. Callen, F. T. Agthe, and J. L. Dynan, Senior students in the Mining Engineering course of Lehigh University, to prepare a report on the Mineral Paint Deposits of Eastern Pennsylvania under the writer's supervision. Their investigations were sufficient to show that the materials suitable for the production of paint were abundant, varied, and widely distributed through the eastern portion of the State and their results published in Bulletin No. 430 of the U. S. Geological Survey (pp. 423-454) form an important contribution to the subject. Owing to the limited amount of time at their disposal and the fact that their observations were made at a time when many of the plants were idle rendered their report somewhat incomplete and less accurate than it would have been under more favorable conditions.

During the summer of 1910 an opportunity was offered to the writer to continue the studies of the mineral pigment deposits of the State under the auspices of the Topographic and Geologic Survey of Pennsylvania. In this connection all the working mines and quarries of the State were visited and the occurrences and geological relations of the ores studied. Many places where mineral pigments were mined in the past were likewise visited and a careful search was made of the literature pertaining to such deposits occurring in Pennsylvania. An attempt has been made to make the report as complete as possible. It is reasonably certain, however, that in the two centuries that have elapsed since the settlement of Pennsylvania these products have been worked in many places long since forgotten while even within the present generation local use has, no doubt, been made of certain deposits not mentioned within these pages. Information concerning such limited use is only obtainable with much difficulty and frequently by mere accident.

The value of a report on any of the mineral products of a region depends upon its circulation among people interested in such materials. At one time it was considered unwise for any firm to permit information concerning its work to become known but at present publicity is not feared, so long as important trade secrets which might enable a competitor to gain the supremacy, are not divulged. Under the stimulus of the Conservation movement the people of the country are demanding information regarding our natural resources and this demand must be met.

The ideal condition in every community is for the proper development of all the natural resources under an active competition that is not so keen as to produce hardship and so injure the business based upon such resources. This is best brought about by the circulation of accurate information and without such knowledge monopolies or ruinous competition may result. The two conditions have been observed in the operation of many of the mineral products of Pennsylvania. In some places certain companies by practicing deception have been able to discourage prospective competitors and by so doing have been able to retain the monopoly of certain industries, demand unjust prices for their wares, and so hinder the full development of the region. On the other hand, in certain places too many firms have started operations in a district because of misinformation regarding the profits with the result that all suffered. Further, the fraudulent promoter of mining stocks plies his nefarious business most successfully where there is least information available. While the mining promoter usually engages in the sale of precious metal mining stocks, yet on the whole much money has been lost on worthless mining properties in this State. The mineral pigment business furnishes some illustrations of such operations in the past but it is to be hoped that these may become less frequent in the future.

The mineral pigments of Pennsylvania are varied and widely distributed. They have not been utilized to their fullest extent in any section nor have any of the products been exhausted except in restricted localities. In some instances the output may be increased with profit but, on the whole, the present production equals the demand and further increase without new outlets being found would merely serve to glut the market and result in hardships, if not actual loss.

In the discussion which follows the mineral pigments are treated under the head of ochers, metallic paint ores, black, yellow, and red shales, iron ores, and minor products.

ACKNOWLEDGEMENTS.

The writer is indebted to the various mineral pigment producers of the State for a large part of the information embodied in this report. He received courteous treatment at the hands of every company and with but two exceptions was given all assistance possible. Without such aid this report would be less complete than it is and grateful acknowledgment is made to the officers of the various companies for data given. He was assisted in the field work by Harvey Bassler, J. C. Stoddard, A. C. Callen, F. T. Agthe, and J. L. Dynan, each of whom has rendered material assistance which is duly appreciated.

CHAPTER II.

OCHERS.

Deposits of ocher occur at many places in Pennsylvania and have been utilized for many years, although there have been few extensive operations. Perhaps more has been wasted than has ever been saved. This is because of its frequent occurrence in association with the brown iron ores which in former years were so extensively worked. In such cases the ocher has usually been regarded as an undesirable product and thrown away. In several places in the State deposits of ocher washed from the iron ores and carried into ponds to avoid interference with the streams have later been utilized. In other places mines have been operated both for iron ore and ocher, while in still other localities the ocher alone is saved and any iron ore that may be encountered is ignored.

Definitions.

The term "ocher" has beeen used in so many different ways that, at the present time, there is considerable confusion in regard to its correct usage. There has been no sharp line drawn between ochers and iron ores and at the present time an important suit in the courts of Cuba involving the ownership of extensive iron deposits may hinge upon the definitions of these two substances. Certain it is, however, that they may possess similar qualities and that one may pass into the other by slight gradations. Certain materials are undoubtedly applicable either to the formation of pig iron or in the manufacture of paints while on the other hand certain substances that are suitable for paint possess little or no value for the production of iron and *vicè versa*.

In this country the term ocher has been applied to both red, yellow, and brown earths that owe their color to oxides of iron, but in Spanish the term is applied only to the yellow earths. The yellow ochers are so much more abundant, however, that when the term is used without any modifying term it is generally understood to refer to the yellow ochers only.

The physical composition of all ochers is the same, viz., loose, earthy, and pulverulent. The chemical composition varies, however, according to the different colors.

Yellow or ordinary ocher contains as its essential constituents clay (hydrated aluminium silicate) as the base and limonite (hydrated ferric oxide) as the coloring matter. Some materials high in iron

oxide and low in alumina and combined silica have been classed with the ochers by some writers but there is now a decided tendency to eliminate from the ochers those substances that are unusually high in iron. Materials containing over 30 per cent. of iron are classed with the iron ores and those of lower iron content are called ochers provided they have the proper physical character and the chemical composition agrees in other respects. Thus ocher is essentially a variety of clay and is so described by Pirsson* who says:

"When pure it (clay) is white but it is generally colored red or yellow by iron oxides, forming red and yellow ochers." A report of the Scientific Section of the Paint Manufacturers Association of the United States† says "ocher is an hydrated ferric oxide permeating a clay base. It has a specific gravity of about 3.5, and a decidedly golden yellow color. A good quality should contain 20 per cent. or over of iron oxide."

Yellow ocher is found in nature and cannot be produced artificially. It is either marketed in its raw condition or burned to form red ocher, the burning process converting the iron oxide into the anhydrous state.

Red ocher differs from yellow ocher only in the condition of the iron. In the former the iron is in the anhydrous form while in the latter, as stated above, the iron is combined with water. Red ocher is found in nature and is also produced from yellow ocher by burning.

Metallic paint is a commercial term that is usually applied to those paint materials that are higher in iron content than the ochers. The term is loosely used and does not represent any definite composition as analyses of materials placed on the market as "metallic paints" have shown the iron oxide to range from 33 per cent. to 64 per cent. In general, the raw substances of metallic paints consist of ocher and limonite iron ore which are ground together and burned to form a red product rich in iron. The limonite iron ore present may constitute a large percentage of the material or may be a minor constituent. It should also be in such a condition that it can be readily reduced to a powder by grinding, although it does not exist in the pulverulent form. The metallic paints are not marketed in the raw condition but are first burned.

Besides the class of metallic paints just described we have another distinct class produced in this State by the burning of carbonate of iron that occurs in a definite bed near Lehigh Gap. These are described in detail in another part of this paper.

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*"Rocks and Rock Minerals," p. 328.

†"The Properties and Structure of Certain Paint Pigments." Bulletin No. 29, p. 19, 1910.

Sienna is an unusually high grade ocher which has long been worked in various places in Italy, particularly near Sienna from which fact it receives its name. It is essentially pure limonite with a small amount of clay and the limonite is all in the pulverulent form, thus differing from the limonite present in the raw products of metallic paint described above. The raw Italian Sienna contains from 60 per cent. to 80 per cent. of limonite.

Sienna is marketed in the raw condition as a deep yellow pigment or burned to produce a dark red substance.

Umber or brown ocher is a variety of yellow ocher in which there is a considerable percentage of manganese dioxide producing a brown color. In Bulletin 29 of the Scientific Section of the Paint Manufacturing Association of the United States the following statements are made: "Umber, another naturally occurring pigment, consists of iron and aluminium silicates, containing varying proportions of manganic oxide, its color and tone varying according to the percentage of the latter. The raw variety is drab in color, which in burning changes to reddish brown." The greater portion of the umber used in this country comes from Turkey. An analysis of raw Turkish umber at hand shows 13.11 per cent. MnO_2 and 48.09 Fe_2O_3.

Umber is used as a pigment both in its raw condition and when burned. The latter product, known as "burnt umber," possesses a dark red to reddish-brown color.

All of the products described are now being produced in Pennsylvania and all except red ocher and metallic paint occur in their natural condition. These are produced by burning.

In the discussion that follows the Pennsylvania deposits will be described under the following heads: yellow ocher, ocherous materials used in the manufacture of metallic paint, sienna, and umber. The red ocher formed by the burning of the yellow ocher will be described in connection with the latter.

YELLOW OCHER.

Distribution.

Yellow ocher occurs at many places throughout the State but has been mainly worked in the Eastern part. Its distribution is practically co-extensive with the limonite iron ores that at one time were so extensively utilized but which, in recent years, have been largely neglected. With few exceptions they occur in the belts of limestone that cross the State in broad or narrow bands in a general northeast-southwest direction. Thousands of such iron mines, some of them with large output, have been worked in these limestone valleys in

Northampton, Lehigh, Berks, Lebanon, Chester, Lancaster, York, Cumberland, Franklin, Center, Blair and other counties, although at present most of them have been abandoned and can now only be located by the depressions that mark the former sites of the operation. These usually contain water and are gradually being filled with material washed from the surrounding regions. They were mainly worked by open cut and were shallow, although underground workings extended to a depth of several hundred feet in some instances.

EASTON-READING DISTRICT.

Geography.

The most important ocher district in Pennsylvania at the present time is a comparatively narrow belt of limestones and quartzites extending from Easton to Reading and enclosed between the gneiss ridges of South Mountain on one side and the slates of Hudson River age on the other. It is comprised in the Easton, Allentown, Slatington, Boyertown, and Reading quadrangles of the United States Geological Survey and lies in the counties of Northampton, Lehigh, and Berks. The same limestone valley continues to the southwest of Reading where, between the Schuylkill and Susquehanna rivers, it is known as the Lebanon Valley; between the Susquehanna and Potomac rivers it is called the Cumberland Valley; throughout Virginia the Shenandoah Valley; and in the Carolinas the Great Valley.

Physiographically the valley between Easton and Reading presents a rolling topography with low round hills and open valleys with an average elevation of about 300 feet above sea level, while the enclosing gneiss hills on the south and southeast are steep and rise to an elevation of 1,000 feet or even more in a few places. The slate belt on the north has a rugged topography with many round topped hills having an elevation of 600 to 700 feet separated by rather narrow steep-sided valleys.

Between Easton and Allentown the Lehigh Valley and Central of New Jersey railroads furnish convenient transportation, while between Allentown and Reading the East Pennsylvania branch of the Philadelphia and Reading Railroad follows closely the line of ocher working. Throughout the belt most of the ocher mines are within three miles of the railroad and as the roads are generally good the cost of haulage to the shipping points is a small item.

Although ocher occurs at many points throughout the limestone valley most of the best deposits lie near the southern rim, on the slopes of South Mountain, or the Durham and Reading Hills as these ridges were designated by the Second Geological Survey of Pennsylvania.

GEOLOGY.

The rocks of this area belong to the Pre-Cambrian, Cambrian, and Ordovician systems. Fossils are rare and good exposures of the rocks are rather few so that the stratigraphy is difficult to determine and only within recent years have satisfactory results been obtained. Even yet many problems remain unsolved and much more detailed work must be done before very definite statements can be made. In the region of Bethlehem where the students and instructors in geology in Lehigh University have been carrying on field work for many years the classification of the rocks given below has been proposed. Whether this classification will be found applicable to the entire belt under discussion must be determined later. It is essentially unlike that proposed by George W. Stose for a similar section in the Cumberland Valley in the region of Mercersburg and Chambersburg and until the intervening distance can be studied it is not considered wise to attempt definite correlations.

TABLE OF ROCK FORMATIONS.

System.	Formation.	Character of Rocks.	Thickness in Feet.	Probable Correlation.
Ordovician.	Martinsburg,	Dark gray to black shales and slates with interbedded sandstones.		{Eden. {Utica. {Upper Trenton.
	Nazareth, -------	Black argillaceous limestone (cement rock).	0–500	Lower Trenton.
	Nisky, ----------	Gray shaly limestones, ---	100	Black River.
	Coplay, ---------	Dark gray motted limestone semi-crystalline with interbedded shaly strata.	1500‡	Beekmantown.
Cambrian.	Allentown, ------	White to gray dolomitic limestone containing oölite.	2000‡	Saratogan.
	Leithsville, ------	Gray dolomitic limestone with shaly layers and chert.	1500‡	Acadian.
	Hardyston, -----	Siliceous conglomerates and sandstones grading into quartzites.	150-400	Georgian.
Algonkian.	Franklin, -------	White crystalline limestone containing flakes of graphite.	?	
	Vera Cruz, -----	Graphitic schist, ----------	?	
Undifferentiated Pre-Cambrian.		Acid and basic igneous and sedimentary (?) gneisses cut by dikes of basalt and pegmatite.	?	

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DESCRIPTIONS OF ROCK FORMATIONS.

Undifferentiated Pre-Cambrian Gneisses.

The gneisses form the range of hills variously termed South Mountain, Lehigh Mountain, and Durham and Reading Hills. There are besides a few outliers of the gneiss within the limestone area lying to the north. The rocks are varied and range from extremely acid varieties composed mainly of quartz and orthoclase to the basic phases in which the ferro-magnesian minerals constitute the principal portion. Much magnetite and ilmenite and considerable pyrite occur in these gneisses and many extensive iron mines in these hills have been operated. The most important are the magnetite mines of Durham Furnace and those in the vicinity of Rittenhouse Gap while scores of others of considerable value have been worked, besides a great number of prospect pits all through the range. The iron content of the gneisses is of interest in the study of the ochers and brown iron ores of the limestone valleys as they indicate the original source of much of the iron. The gneisses have been subjected to so much weathering that in many places the rock is sufficiently decaved to depths of 25 to 75 feet from the surface that it crumbles readily and many large sand pits have been opened on the slopes of the hills. The material is screened to remove the less disintegrated portions and used for building purposes and as a moulding sand.

Vera Cruz Graphite Schist.

The rocks belonging to this formation have a limited distribution in this region. They occur about 2½ miles north of Bethlehem near Quaker Hill, about one mile east of Emaus, in the vicinity of Vera Cruz Station, several places south and southwest of Seisholtzville, near Longswamp, and west of Boyertown. The rocks consist of quartz, graphite, biotite, orthoclase, and some pyrite. Graphite mines have been opened in these schists at several points but everywhere there has been considerable difficulty in separating the graphite and biotite and all operations have been abandoned.

Franklin Limestone.

The Franklin limestone, correlated with the coarsely crystalline limestone of Franklin Furnace, New Jersey, outcrops in a small area in the vicinity of Quaker Hill, 2½ miles north of Bethlehem, adjacent to an area of Vera Cruz graphite schist. It is a white, thoroughly crystalline limestone, containing many small flakes of graphite.

Hardyston Quartzite.

The Hardyston formation overlies the gneiss of South Mountain and is composed of varied materials. In many places the basal portion consists of an indurated soil formed from the decayed portion of the underlying gneiss in which are angular pieces of quartz with an occasional rounded quartz pebble. The indurated kaolin is of a light green color in most places resembling serpentine but in a few places it is stained by iron oxide to such an extent that it resembles red jaspar. This old soil bed is seldom more than four feet in thickness. It forms a gradation between the gneiss and the overlying sandstone or quartzite and may properly be classed with either. Above the indurated soil stratum occur beds of siliceous rocks ranging from conglomerates with pebbles an inch or more in diameter to quarzites in which the individual grains of quartz cannot be distinguished. The basal beds are stained with iron, a rusty brown in most places, but the upper strata are so white that they furnish excellent building stone. In some places kaolin derived from the adjacent gneiss forms a prominent constituent of the lower strata. The most unusual phase of the formation occurs in the Saucon Valley and along the northwest flank of South Mountain near Emaus where secondary changes have converted the rock into a ferruginous chert, chert breccia, or brown iron ore. In the alteration which has been produced by ascending and descending waters along a fractured zone all traces of bedding planes have been obliterated. Great masses of this rock occur a short distance northeast of Emaus while broken blocks cover extensive areas there and in the vincinity of Hellertown. The Indians made use of this rock in the manufacture of their arrow heads and several of their old work shops have been located in the vicinity of Emaus.

The Hardyston formation has yielded few fossils in this region, the only ones being a few spines of *Olenellus* about one-half mile southwest of Old Zionsville and specimens of *Scolithus linearis* that are abundant in the region between Macungie and Reading but exceedingly rare between that place and Easton.

The formation is about 150 feet thick in the region of Bethlehem but increases in thickness toward Reading to about 400 feet.

Leithsville Shaly Limestone.

Overlying the quartzite and sandstones of the Hardyston formation is a considerable thickness of shales and shaly limestones with occasional strata of compact thick-bedded dolomitic limestones in which there are many nodules of black to gray chert. They outcrop at the base of the South Mountain hills and are in many places

entirely concealed from view by the talus of the more resistant gneiss and quartzite which outcrop at higher levels. Fossils seem to be entirely absent, suggesting a chemical origin for the limestones. The thickness of the strata of this formation is about 1,500 feet.

Allentown Limestone.

The Allentown formation is composed of massive beds of dolomitic limestones, white to gray in color. Outcropping to the north of the Leithsville strata and farther from the steep slopes of South Mountain there are many excellent exposures of the formation in the southern portion of the great limestone valley. The limestones are so soluble that caverns are common in the regions where these rocks occur and many houses and even towns make use of these underground passages in the disposal of their sewerage.

The only fossil thus far recognized in this formation is *Cryptozoon proliferum*. It occurs in rounded heads varying in diameter from 1 inch to $1\frac{1}{2}$ feet. Closely associated with these fossils are layers of oölite. In most cases a band of oölitic limestone several inches in thickness underlies the stratum containing the colonies of *Cryptozoon proliferum*.

The thickness of the Allentown limestone is apparently about 2,000 feet. The absence of any continuous section across the entire formation and the presence of several strike faults render the exact determination of the thickness impossible.

Coplay Limestone.

The lowest member of the Ordovician period in this region is the Coplay formation that is well exposed in several places along the Lehigh River in the vicinity of Coplay. Lithologically it is a heterogeneous limestone composed of small irregular bodies of light and dark material. Some shaly layers are also present. Some of the layers consist of almost pure $CaC0_3$ and have been used in the manufacture of cement while interbedded strata are dolomitic. In general the dolomitic layers are whiter than the others and can be readily detected in the quarry openings.

Fossils have been found in the rocks of this formation at many points in the vicinity of Bethlehem and Coplay. They are not very well preserved but yet it has been found possible to determine the following forms:

Helicotoma sp.
Liospira (?) sp.
Syntrophia lateralis.
Protowarthia rossi.
Ophileta complanata.
Eccyliopterus volutatus.

Dr. E. O. Ulrich who made the determinations considers the formation to be the equivalent of the Beekmantown of New York. The thickness of the formation is about 1,500 feet.

Nisky Limestone.

Gray shaly limestones immediately underlying the cement rock constitute the Nisky formation. The formation, although only about 100 feet thick, is of great economic importance because of the extensive use made of these limestones in the manufacture of Portland cement. Magnesium is either very low or altogether lacking and the rock is therefore well suited for mixing with those shales that are deficient in lime in order to get the correct composition for the best grade of cement. Fossils are not abundant although they have been found in several places. The following species have been determined from quarries near Nazareth:

Receptaculites occidentalis,

Plectambonites sp.

Pachydictya sp.

Fragments of crystals and crinoids.

Dr. E. O. Ulrich considers the fauna the approximate equivalent of the Black River of New York.

Nazareth Limestone.

The Nazareth formation, consisting of a gray to black shaly limestone that has been so extensively utilized in the manufacture of cement in the Lehigh Cement District, outcrops along the north side of the limestone valley extending from the Delaware River to the Schuylkill River. In this narrow belt are located many of the largest cement mills of the country and only a few years ago 90 per cent. of the cement product of the United States was manufactured here, while at present the district contributes about one-third of the total product.

The Nazareth limestone is not continuous and its absence in certain localities is explained by its passage into shales that are not separable from the overlying Martinsburg shales. The maximum thickness is probably about 500 feet. The crumpling which it has undergone by which bedding planes have been obliterated in many places render the determination of the thickness somewhat indefinite. *Mesotrypa quebecensis* has been found in several places in this formation together with fragments of other fossils.

Martinsburg Shales.

The difficultly soluble black shales of the Martinsburg formation bound the limestone valley on the north as do the slightly soluble gneisses and quartzites on the south side. Near the base of the formation the shales have become sufficiently metamorphosed to permit certain strata to be used for roofing slates, and several slate quarries were formerly worked in this part of the Martinsburg shales in the vicinity of Nazareth and Bath. The middle portion of the formation contains many interbedded layers of dark colored sandstones and no workable slate, while the upper part consists of shales alone and contains many extensive slate quarries in the vicinity of Bangor and Slatington.

These shales contain considerable pyrite in certain places and where the shales have weathered they are colored a rusty brown by iron oxide that was probably derived from pyrite. The presence of small quantities of pyrite is of interest in the determination of the origin of the brown iron ores of the limestone valley.

Structure

The structure of the rocks of the great limestone valley and the hills bounding it on either side is far from simple. In general the strata dip to the north so that in crossing the valley from south to north one successively encounters younger rocks ranging from the pre-Cambrian gneisses on the south to the Ordovician Martinsburg shales on the north. Folds and faults interfere with this general order in many places and the true structure is only determined with difficulty.

Several systems of folds occur with their axes running in different directions. Most of the major and many of the minor folds have a northeast-southwest direction but some have their axes at almost right angles to the general trend. Some of the larger folds involve thicknesses of 3,000 to 4,000 feet of strata although most are of much less magnitude. Near Hokendauqua and Stenton many complicated folds involving 50 to 100 feet of strata are well exposed while small crumplings are numerous. In that region many of the folds are overturned and some have passed into thrust faults.

The faults of the region are likewise numerous and complicate the structure considerably. They are mainly normal strike faults although thrust strike faults and normal dip faults are also present. The throw is sometimes several thousand feet. Such a fault is responsible for the area of pre-Cambrian rocks constituting Quaker Hill, a few miles north of Bethlehem, almost in the center of the limestone valley, while other small detached areas of gneiss surrounded by limestones owe their position to similar faults. Likewise faults are

the cause of certain areas of slates that extend into the limestones. The largest of such slate areas is Huckleberry Ridge, a few miles west of Allentown, that has been caused by a normal fault of considerable throw that has brought the slate into the belt of limestone.

DESCRIPTION OF OCHRE DEPOSITS.

Distribution.

The ochers of the Easton-Reading district are closely related to the geology and structure of the region. Some earlier writers have claimed that the brown iron ores, with which the ochers are almost invariably in association, are much more common along the northern side of the valley adjacent to the Martinsburg shales; others have held that there was no definite order of distribution; while still others have maintained that they occur in those places where there are shaly strata.

In this region there are many iron and ocher mines along the south side of the valley on the north flank of South Mountain, some on the opposite side of the valley close to the Martinsburg shales, while others are distributed irregularly throughout the valley. They occur in each of the formations from the Hardyston to the Nisky and possibly in the Nazareth although no example is known to the writer of such occurrence. Notwithstanding this varied distribution, a certain regularity can be noted. The deposits are most abundant in those rocks that are easily replaced and are consequently absent in the gneisses and slates. Of greater importance, however, is the relation existing between the structure of the region and the ore deposits. The writer is not prepared to say that all the limonite and ocher deposits occur in places where there has been intense folding or faulting, but certainly most of them do. The result is that many of the iron mines occur in a more or less straight line, roughly parallel to the strike of the beds. The miners themselves have recognized this and have profited by it in their prospecting for ores without, however, appreciating the full significance of the orderly arrangement. As examples of the relation of faults and iron mines we have a line of iron mines about two miles southeast of Hellertown following a fault; a long line of old mines about 1 to 2 miles northeast of Emaus following a pronounced fault which can be traced by numerous slickensided surfaces; a line of iron mines following the fault on the north side of Huckleberry Ridge; and the extensive iron workings at Ironton that likewise extend along a fault for a distance of about half a mile.

Occurrence.

The ocher, as already stated, usually occurs in close association with the brown iron ores. They occur either in pockets of small or large size irregularly distributed throughout clays that range in color from white to yellow, to red, to black or in rather definite layers, perhaps representing the strata of the original rocks that have been wholly replaced. The accompanying sections shown in Fig. 1 taken from a brief report by Stoddard and Callen* shows the relation of the clay and ocher in one of the largest ocher mines of the district. Some of the pockets of ocher are several feet in diameter and it is possible to remove the material without taking out much clay. In other cases, however, the ocher is in such small masses that much clay must also be removed and the mixture forms a low grade ocher. The clay cannot be removed from the ocher by washing and settling, hence the best grade of ocher can only be obtained where it occurs in large pockets or thick layers.

The ochers and associated clays lie upon the older rocks, in the main, and represent the residual insoluble material left in the disintegration of the limestones or replacements that have occurred along fractured or faulted zones. The deposits are all superficial and occupy irregular basins that vary greatly in diameter and depth. In the vicinity of Fleetwood the clay and ocher were found to extend to a depth of at least 257 feet but in most cases the underlying unaltered rocks are encountered within 100 feet of the surface. Ridges or pinnacles of limestone sometimes rise several feet above the general level of the basin floor while occasional steep-sided pits extend a considerable distance below.

Limonite ore which represents a more concentrated condition of the hydrated iron oxide than the ocher is present in all the ocher mines either distributed throughout the ocher and clay irregularly or arranged in rather definite layers alternating with the bands of ocher. The former condition is the more common and considerable iron ore is removed with the ocher and accumulates about the mine until there is sufficient to warrant a shipment to some furnace. At Fleetwood the upper levels of the present working ocher mines were at one time operated for the iron ore and the ocher discarded while at present the nodules of limonite removed with the ocher constitute the by-product. In some cases the limonite is present in small masses that can be easily ground to a powder and the combined material is used in the manufacture of a metallic paint.

The limonite occurring with the ocher is in the form of nodules or geodes either hollow or filled with clay, sand, or water and commonly termed "bomb-shells" by the miners; as hollow tubes or pipes; as a brecciated mass; or as fragments of broken nodules.

*Ocher Deposits of Eastern Pennsylvania, U. S. Geol. Surv., Bull. No. 430, pp. 424-439, 1910.

Besides the limonite masses in the ocher pits of Henry Erwin and Sons, at Topton there are small masses of chalcedony that resembles clusters of berries some of which are more than an inch in diameter. These are evidently secondary as they bear no resemblance to the chert nodules that occur in the limestones.

In many of the ocher and brown iron ore mines large masses of dark colored chert are encountered. At Sampson's ocher mine south of Easton these are particularly abundant and also numerous in Williams' mine near Reading. These masses are not uncommonly several feet in diameter. They probably represent the chert nodules that were originally present in the limestone and have been left as a residuum in the clay when the enclosing rocks were disintegrated although the fact that they are so much larger than any that have been observed in place in the limestones suggests their possible origin by the precipitation of silica carried upward by deep-seated waters along fault planes. As already described, the Hardyston quartzite in some places in the vicinity of faults has undergone marked secondary changes by which it has been converted into a brown chalcedony.

Origin of the Ocher.

The origin of the limonite and ocher deposits of Pennsylvania has been discussed by many writers and many different explanations advanced. H. D. Rogers* believed that the iron came from the overlying slates in which the iron existed in the form of pyrite. Prime† says they have been formed in place by the decomposition of ferrous silicates or ferrous carbonate originally present in the limestones. d'Invilliers** states that they are produced by the decomposition of pyrite originally present in the shaly strata intercalated with the limestone. Hopkins†† says "the original source of the iron is primarily the Cambro-Ordovician limestones and slates, with smaller quantities from the overlying Ordovician and possibly Silurian strata and the underlying slates and quartzites. The iron occurs in these strata as carbonate, sulphide, and silicate, the first being probably the most common."

Undoubtedly the source of the iron of the ocher is not confined to a single group of strata. The rocks of every formation in the region contains more or less iron. In the gneiss the iron exists in large quantities, primarily as magnetite but in considerable quantities as pyrite. The Hardyston quartzite contains hematite, pyrite, and limonite and the Leithsville, Allentown, Coplay, Nisky, and Nazareth formations contain much iron chiefly in the form of the carbonate, but

*Geology of Pennsylvania, Vol. I, p. 183. 1858.
†Second Geol. Surv. of Pa., Report D, pp. 53 and 59.
**Second Geol. Surv. of Pa., Report T, p. 136.
††Cambro-Silurian Limonite Ores of Pennsylvania, Bull. Geol. Soc. Amer., Vol. XI, pp. 475-502, 1900.

also iron sulphide and iron silicate which, where exposed to the atmosphere, have been largely converted into limonite. Analyses* of seven limestones from Lehigh county show from 0.538 per cent to 4.06 per cent. of $FeCO_3$ with an average of 1.568 per cent. and from 0.03 per cent. to 0.611 per cent of FeS_2 with an average of 0.269 per cent. The pyrite is undoubtedly mainly present in the shaly beds while the iron carbonate exists in the purer limetsones. The overlying Martinsburg shales have also contributed some of the iron which exists in these strata mainly in the form of pyrite. About 2 miles northwest of Breinigsville copperas (ferrous sulphate) formed from the pyrite in these shales is said to have been worked at one time.

Although the iron content in all the strata of the region is small the amounts are sufficient to account for all the ochers and brown iron ores of the region. The problem remaining is to account for the alteration of the original iron compounds and the segregation of the resulting iron minerals in their present positions. There is no question but that these changes have come about during the decomposition of the enclosing strata. Oxygenated waters would tend to convert the sulphide into the soluble sulphate and in that form it was readily transported. Further oxidation would tend to convert it into the less soluble hydroxide and as such it was precipitated about some center to produce limonite geodes or in a more finely divided condition throughout the clay to form ocher. The iron carbonate and iron silicate were dissolved by waters charged with carbonic oxide or organic acids and where the solutions later flowed through limestones the iron being less soluble than lime was finally dropped and lime was taken into solution instead.

Meteoric waters are responsible for the concentration of the ores as they dissolved the original iron minerals, carried the iron solutions in their passage through the rocks and precipitated them along the main water courses. It is a well-known fact that faulted and greatly fractured zones are favorable places for the passage of water and that is why so many of the ocher and brown iron ore mines are located along the belts where the rocks have been most disturbed.

Age of the Ocher Deposits.

The accumulation of the iron which was originally distributed in small quantities throughout a great thickness of strata began as soon as the strata emerged from the sea in the late Palezoic and continues even at the present time. In the limestone valley a total thickness of several thousand feet of materials has been removed mainly by solution and a considerable portion of the iron has been left together with the other insoluble materials which constitute the clay.

*Second Geol. Surv. of Pa., Reports M 2 and M 3.

Some of the iron of the overlying Martinsburg shales also remains but a less percentage for the reason that the shales are removed by corrasion and much of the contained iron is carried in the shale particles. The same is true of much of the iron of the gneiss although the gneisses of South Mountain rising several hundred feet above the valley have undoubtedly contributed considerable iron to form the ocher and limonite deposits that occur near the base.

Methods of Mining.

The ocher is mined both by open cut and by means of shafts. The former method is employed wherever the ocher lies within 10 to 15 feet from the surface and shafts are sunk where the ore lies deeper. The pockety character of the ore and the uncertain market for the product do not justify elaborate equipment and the mines cave soon after operations cease. Little timber is used in some mines except in the shafts and main drifts but if much water is present the squeezing action of the clay requires much timber even in the small stopes.

In most of the mines the ocher is found to extend in a more or less definite band and drifts following the ore bodies are run from the shaft in either direction. When a pocket of ore is found which extends upward over head stopes are opened. In drifting the stringers or pockets of ore are followed wherever found and when they die out the drifts may be run in almost any direction but mainly in a direction parallel to the course of the principal bodies where there seems to be such an arrangement of the ore. The ore is trammed to the shaft by means of wheel-barrows and hoisted to the surface in buckets where it is washed and prepared for shipment.

The power necessary for hoisting, running the washing plant and grinding machinery, and operating the pumps is furnished by a small steam plant. Cornish pumps take the water from the mines or nearby wells for the washing of the ocher.

Preparation of the Ocher for Market.

As the ore comes to the surface it is mixed with clay, limonite nodules and fragments, and pieces of chert. The clay cannot be removed by washing but the hard particles can. The common log washers which are used are very effective and the ocher and clay are washed out at the lower end while the hard particles are pushed out at the upper end. The better part of the iron ore is picked out by hand and thrown to one side where it accumulates until there is enough to make a shipment to some nearby furnace.

The ocher and clay are washed into a series of settling troughs that are slightly inclined so that the water passes through them rather slowly. The current is further retarded by baffle boards behind

which the coarser particles settle. At one of the Fleetwood mines of C. K. Williams & Co. the water from the log washer carrying the suspended patricles of ocher and clay passes through 28 troughs 14 to 16 feet long and 13 inches wide. The coarsest sand settles in the first 2 or 3 and the sediment diminishes in size in each trough until the last one is reached where the little sand present is extremely fine. Thence it passes by means of a long trough to settling ponds that are formed by digging a few feet in the surface and throwing the excavated material up to form an embankment. These settling ponds are roughly rectangular in shape and vary in size. An average size is probably about 40 feet long, 25 feet wide, and 3 to 4 feet deep. These are frequently in series so that the finest material will pass from the first pond into the second. The overflow from the last pond is carried off through a pipe. It is possible to grade the material by turning the best grade of ocher brought to the surface into a certain pond while that having a large admixture of clay into another pit. When a pond is full the surplus water is allowed to evaporate. This may require from a few weeks to several months depending upon the weather. When it finally reached a condition where it can be readily shoveled it is dug and hauled in wheelbarrows to the drying sheds where it is placed on long open shelves for final drying. In a few places steam drying sheds are used but most of it is air dried. Henry Erwin & Sons at Topton have a steam dryer with a capacity of about 15 tons for use in winter when air drying is impossible.

From the drying sheds the material is either hauled directly to the railroad for shipment or else ground in French buhr mills and then shipped in bags or barrels.

In the case of the mud dam deposits about the old iron mines the ocher is dug in those places where there is the smallest amount of sand and washing may not be necessary. In some places ocher of almost as good quality can be obtained as that which has been carefully washed with the purification of the ocher in mind rather than the separation of the ocher for the purpose of preparing the iron ore for market. In these old mud dam deposits, however, the ocher is apt to have a greater proportion of clay and sand and washing may be necessary to remove the latter. In some of the extensive deposits that accumulated about the large mines that were worked for many years it is usually possible to find several layers of fairly clean ocher.

Development of the District.

The history of the ocher industry in Eastern Pennsylvania is not known with much certainty. Ocher has been dug continuously throughout the belt during the last 40 years and probably was utilized in smaller amounts at as early a date as the iron ores of the region

which have been worked ever since early Colonial days. The life of a single mine seldom lasts many years but on the exhaustion of one deposit it is usually easy to locate another. The market and not the supply obtainable has always been the chief factor in the development of the ocher industry. The paint manufacturers of the country demand a limited amount of American ocher and it is impossible to compete in the foreign markets with some of the European ochers hence the extension of the industry does not offer special inducements. At present the greater proportion of the ocher is mined by the paint manufacturers themselves and the operator who did not wish to manufacture the ocher into paint might experience difficulty in finding a market. Until a wider field can be found for the material it therefore seems improbable that we shall see much greater development than at present.

DESCRIPTION OF INDIVIDUAL PROPERTIES.

Plant of A. K. S. Sampson, Easton, Pa.

About three-fourths mile south of South Easton on the north flank of South Mountain, Mr. A. K. S. Sampson is operating an ocher mine in a region where brown iron ores have been extensively worked for more than fifty years. The iron ore and ocher occur in intimate association so that both are removed in mining. Until recently the ocher was regarded as of no value and after being washed from the iron ore in a log washer was drained into settling ponds. C. K. Williams of Easton discovering that the ocher thrown away could be readily washed and a good grade of material secured entered into an agreement with Mr. Sampson by which Mr. Williams constructed sand troughs and settling pits and paid Mr. Sampson a small sum per ton for the finished product. Under this agreement a large amount of ocher has been obtained as a by-product.

Investigation of the extensive mud-dam deposits that had accumulated throughout the long period of time that the iron mines had been operated showed the presence in certain portions of fairly good ocher notwithstanding the fact that no attempts had been made to free the ocher from the sand and clay in the washing. Naturally the portion of the deposit near the point where the material entered the pond was found to contain much sand so that it could not be used without careful washing, but that portion farthest from the entering troughs was found to be practically free from coarse particles and

suitable for paint. A considerable amount of this deposit has been dug by C. K. Williams & Co. of Easton and Henry Erwin & Sons of Bethlehem. An analysis of the material furnished by the latter firm follows:

SiO_2,	39.70
Fe_2O_3,	37.64
Al_2O_3,	12.36
MgO,	1.37
Moisture,	7.83
	98.90

An analysis of the same ocher when burned is as follows:

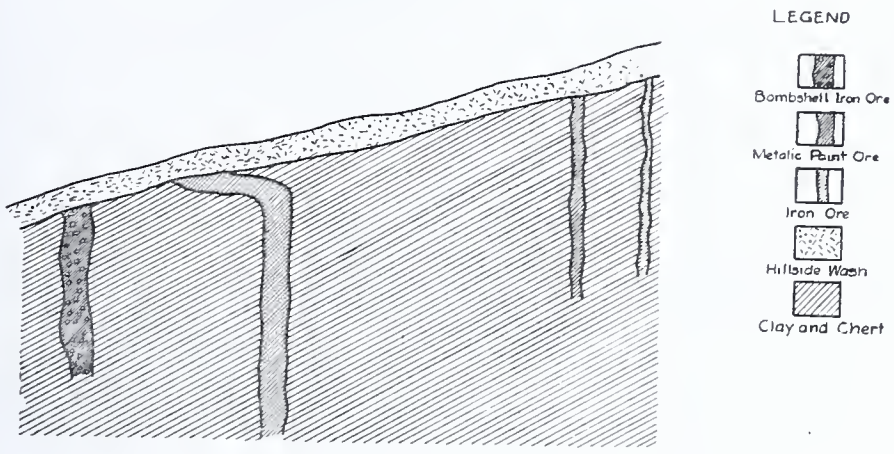
SiO_2,	39.00
Fe_2O_3,	42.35
Al_2O_3,	13.33
MgO and SO_3,	Traces
Moisture,	2.50
	97.18

Recently iron mining has been abandoned in the region and a shaft was sunk for the purpose of obtaining ocher alone. The shaft is 207 feet in depth and drifts have been run off at several levels. The shaft is located a few rods from the last iron mine shaft and a pump in the latter frees the ocher mines from water.

The ocher ore mined is deep yellow in color and contains much limonite, the most of which occurs in small loosely indurated masses. Some hard limonite geodes and chert fragments are mixed with the ore but these are easily picked out by hand. The softer pieces of iron ore are not removed but are ground with the ocher and the mixture of iron ore and ocher used in the manufacture of "metallic paint." All the material is sold to C. K. Williams & Co. of Easton who report that the product varies greatly in composition, ranging from 20 per cent. to 60 per cent. oxide of iron (Fe_2O_3), the balance principally SiO_2 and Al_2O_3. The great range of iron oxide is due to the varying amount of limonite present in the mixture.

The ocher and also the iron ore previously worked lie in apparent veins that are either practically vertical or with a steep dip to the north and run in a general east and west direction parallel to the South Mountain range. According to Mr. Sampson four parallel "veins" of iron and ocher occur here, occupying the positions shown

in the accompanying diagram. The "vein" farthest down the mountain was worked for the iron ore with the ocher as a by-product, while the others contain too small an amount of iron to warrant their operation for iron ore but furnish a high grade "metallic paint" ore. Much light-colored clay occurs with the ocher but is discarded. The bands between the so-called "veins" consist of clays of various colors with much chert.



Scale 200'=1"
FIGURE 1 SECTION SHOWING OCCURENCE OF ORE BODIES IN MINE OF A. K. S. SAMPSON, EASTON, PENNA

No outcrops of rock occur near the mine nor were any rocks in place observed in the mine. Mr. Sampson states that limestone in place was found in contact with the iron ore layer. The position of the ore bodies and their character seem to indicate their origin from the decomposition of the basal beds of the Leithsville limestone, the masses of chert, ore, and clay representing the residual insoluble portions of the original rock. Some of the iron oxide has become segregated to form the limonite nodules while some occurs evenly distributed throughout the clay forming the ocher.

The amount of ocher mined is about 2,500 tons a year.

Mine of the Victor Mining Company, Wescosville.

The Victor Mining Company with offices at 140 Maiden Lane, New York City, and also in Alburtis, has recently opened an ocher mine 3-4 mile south by west of Wescosville on the farm of Hiram Hiskey. The shaft sunk during the summer of 1910 is located beside an old open-cut limonite iron mine that was abandoned many years ago and close to the spot where a decade previously another shaft was sunk to obtain ocher for the Bass Paint Company then operating a mill at Alburtis. The earlier attempt was not successful and the mine was soon abandoned.

The present shaft is 52½ feet in depth and according to Mr. M. H. Shankweiler, General Manager, the following materials were penetrated in sinking it.

	Feet.
Light yellow clay containing some streaks of red clay and occasional pieces of iron ore,	35
Layer of limonite iron ore in clay matrix,	6
Gray clay,	2
Ocher containing much fine iron ore and some large geodes of hard limonite,	9½
Gray clay not penetrated.	
Total,	52½

Drifts have been run in the ocher bed at the bottom of the shaft a short distance only. The material is hoisted to the surface by a windlass and the coarse iron ore picked out by hand and the ocher with the fine limonite particles hauled to the mill of the Prince Metallic Paint Company at Alburtis.

The ore and clay occupy a solution depression in the limestone and the bottom of the shaft is probably near the bottom of the residual material as a well nearby struck limestone at a depth of about 50 feet.

Up to the present all the material mined has been sold to the Prince Metallic Paint Company at Alburtis for use in the manufacture of metallic paint. It is not washed but fed directly into a rotary kiln 30 feet in length and 30 inches in diameter rotating at a speed of one revolution in 55 seconds. The fuel used is bituminous coal which is burned in a furnace at lower end of kiln. After burning the material which has acquired a dark red color is ground very fine in a Sprout-Waldron vertical grinder and then packed in bags holding from 70 to 100 pounds, in kegs holding 100 pounds, or in barrels holding 300 pounds. The material is sold under the trade name of "Single Label Metallic Paint."

Abandoned Ocher Mines 1½ Miles N. W. of Alburtis.

For about 15 years ocher was mined on the adjoining farms of Samuel Butz and Reuben Deysher, 1½ miles N. W. of Alburtis, but the supply having been practically exhausted they have recently been abandoned. The material obtained on the farm of Mr. Deysher was mainly hauled to a paint mill at Mertztown while that from Mr. Butz's farm was taken to Alburtis where it was used in the manufacture of Prince's Metallic Paint.

The material obtained was similar to that occurring in the mine previously described and was used in the same way. The larger harder pieces of limonite were picked out and the remaining mixture of ocher and fine limonite burned without washing and later ground.

Plate I.—Plant of Bear Bros., Breinigsville.

The mines were worked both by open cut and by shallow shafts, some of which were 40 feet in depth. Little timbering was necessary. The ore and associated clay represent the residuum left when the soluble portion of the limestone was removed. No rock in place is exposed in the region nearby and the writer could not learn whether any limestone was encountered in the workings. Most of the shafts have now caved so that few observations could be made.

Bear Brothers Plant 1½ Miles N. W. of Breinigsville.

The ocher mine and mill of Bear Brothers located 1½ miles N. W. of Breinigsville was not in operation when visited in August, 1910. The mine was worked by a shaft now filled with water located by an extensive abandoned open-cut limonite iron mine. This mine is described by Frederick Prime, Jr., in his report* on the "Brown Hematite Ore Ranges of Lehigh County" and his description is quoted.

"Francis Breinig's Mine, No. 17. The large pit is full of water; it has not been worked since 1860, and is said to be exhausted. To the right is a smaller opening, which is being worked at present. The ore occurs in seams and streaks in damourite slate, and the white and yellow clays formed by its decomposition. The clay and ore pitch 18° to 25°S.80°E. The portion of the mine worked is 50 feet deep, and does not exhibit any sign of the ore being exhausted. There is a plane for hoisting the ore. The daily capacity of the mine is 20 tons of ore; 20 men and boys are employed. Mr. M'Creath analyzed the ore, and found:

Iron,	48.100
Manganese,	0.360
Sulphur,	0.045
Phosphorous,	0.164
Insoluble residue,	13.440

"In the northern portion of the field in which the mine is situated a blue ochre is obtained, which is used as a paint. It is probable that this ochre is decomposed *Utica Shale.* An analysis by Dr. Genth gave the following result:

Loss by ignition in closed crucible (water),	4.84
" " " " open crucible (graphite),	4.26
Quartz,	44.50
Combined silica,	26.25
Alumina with traces of ferric oxide,	17.95
Magnesia,	0.94
Alkalies, etc., (not determined),	1.26
	100.00

*Second Geol. Surv. of Pa., D, 1875, pp. 32-33.

"To the south of the large abandoned opening there are two smaller ones, also full of water. This mine lies 1½ miles northwest of Breinigsville. The clay from the mud-dam is dried and sold as yellow ochre for the preparation of paint. Mr. M'Creath's analysis shows it to contain:

Silica,	60.53
Alumina,	17.40
Ferric oxide,	9.29
Lime,	0.08
Magnesia,	1.92
Water,	5.51
Alkalies (by loss),	5.27
	100.00

In the same report Prime describes another mine in the same vicinity and states that "the mud from the mud-dam, which is ochre-yellow in color, is carefully dried and then sent as ochre to the Blue Mountain Paint Company at Bethlehem. Mr. M'Creath analyzed it and found

Insoluble residue,	55.88
Alumina,	19.40
Ferric oxide,	10.57
Lime,	0.08
Magnesia,	1.71
Water,	8.17
Alkalies,	3.76
	99.57"

The iron mine is located at the contact of the Martinsburg Shales and the underlying limestones. The plant consists of a boiler and engine room with machinery to hoist the ocher up the shaft which has two compartments and for pulling the loaded cars up an incline from the shaft to the log washer. From the log washer the ocher was transported to settling basins in the pits of old open cut iron mines. Thence after the preliminary stage of drying, it was taken to open air drying sheds. The dried ochre was ground in a Sprout-Waldron mill, then elevated and by means of a screw conveyor carried to tubes down which it passed into barrels or sacks for shipment. Some of the ocher was burned in a small rotary kiln but most was shipped as raw ocher. The water was pumped from the mine by a Cornish pump and this water used in the log washer.

Plate II.—Mud Dam Deposit 1 Mile N. E. of Trexlertown.

Mud-dam Deposit 1 Mile N. E. of Trexlertown.

On the farm of Jerry Gramme, 1 mile N. E. of Trexlertown, ocher is being dug from an old mud-dam deposit beside an immense abandoned open-cut limonite iron mine now filled with water. The deposit is about 15 feet in depth and covers more than 2 acres. At the end of the old pond farthest removed from the point where the water from the washer carrying the suspended sand, fine ore, ocher, and clay entered, the ocher is fine and no doubt large quantities of fairly clean material can be obtained. Certain layers have a deep yellow color and these are the ones now being worked. The ocher is hauled to the mill of the Prince Metallic Paint Company at Alburtis where it is crushed, ground and shipped as raw ocher.

The deposit of iron and associated ocher probably occupy a depression in the Coplay limestone although no exposures of rock in place were observed in the vicinity of the mine.

Mud-Dam Deposit 1½ Miles N. E. of Trexlertown.

One and one-half miles N. E. of Trexlertown, on the farm of William J. Smith, ocher has recently been dug in an old mud-dam deposit produced from the ore washings when a large open pit limonite iron mine on the opposite side of the road was operated. The material differs from that described in the previous deposit in that it has a decidedly reddish color. It is hauled to the plant of the Prince Metallic Paint Company at Alburtis, where it is burned, crushed, ground, and marketed under the trade name of "Terra Cotta."

Ochre Mine of Dr. Wilson P. Long, ½ Mile S. W. of Hancock.

On the farm of Dr. Wilson P. Long somewhat less than one-half mile southwest of Hancock, ocher has been dug in a number of places. The number of openings is due to the difficulty that has been experienced in the mining in this locality as the squeezing of the clay destroys the timbering of the shafts and drifts and necessitates the abandonment of the mines after a short time. The ocher occurs in association with iron ore nodules, chert fragments, and much clay in irregular pockets of variable size. The ocher is separated from the clay as well as possible during the mining but no washing plant or mill has ever been constructed. Most of the shafts through which the ore has been extracted have a depth of 30 to 40 feet, although some are said to have been sunk to a depth of 80 feet. The band in which the ocher is more or less concentrated is said to dip to the southeast. When visited during August, 1910, one man alone was engaged in mining. He had sunk several shallow test pits in some of which ocher had been found. The shaft worked during the preceding winter had been abandoned. The entire output of the mine is sold to C. K. Williams & Co. of Easton.

Mud-Dam Deposit, ½ Mile S. W. of Hancock.

A short distance west of the preceding property is an extensive mud-dam deposit belonging to the Thomas Iron Company. The deposit covers about two acres and is several feet in depth. It represents the washings from the brown iron ore extracted from a large iron mine a short distance farther up the hill from which a great amount of ore was taken many years ago. The ocher deposit has been prospected and fairly good material found although, so far as known, none has been shipped.

Plant of Henry Erwin & Sons, ½ Mile S. of Topton.

The ocher mine and washery of Henry Erwin & Sons, located one-half mile south of Topton, is one of the largest in the district. It has been operated for over 30 years during the summer seasons and shows no indication of exhaustion. It is worked now entirely by open-cut although at one time there were several shallow shafts through which the ocher was removed, the timbering of which is now exposed at one side of the open cut. The pit is about 45 feet in depth at the deepest point, is approximately 300 feet in greatest length and about 100 feet wide at the widest place. In some parts of the pit the ocher lies within 2 or 3 feet of the surface but in other parts it has an over-burden of float rock and soil 5 to 8 feet thick.

The ocher is not uniform in character and much of it is too light in color to be utilized. No regularity of arrangement of the variously colored materials is apparent. Mixed with the clay and ocher are many nodules of limonite partly filled with white clay and ranging in size from 1-8 inch to 1 foot in diameter. In shape they are unlike the ordinary limonite geodes found in association with the ochers elsewhere in that a large proportion of them have a neck or tapering projection half as long as the main nodule.

In addition to the limonite geodes there are many angular chert particles, some of which are 8 to 10 inches in diameter. These have been derived from the limestone and left behind, together with the other insoluble materials forming the clay and ocher, when the calcium carbonate was removed in solution. Besides, in certain places in the ocher and clay there are unusual aggregations of chalcedony resembling bunches of berries. These are, in the main, less than 1 inch in diameter, although a few were noted somewhat larger. They are unlike any siliceous nodules observed in place in the limestone and their origin is problematical.

Plate III.—Open Cut Ocher Mine of Henry Erwin & Sons, Topton.

Plate IV.—Boiler House and Drying Sheds of Henry Erwin & Sons, Topton.

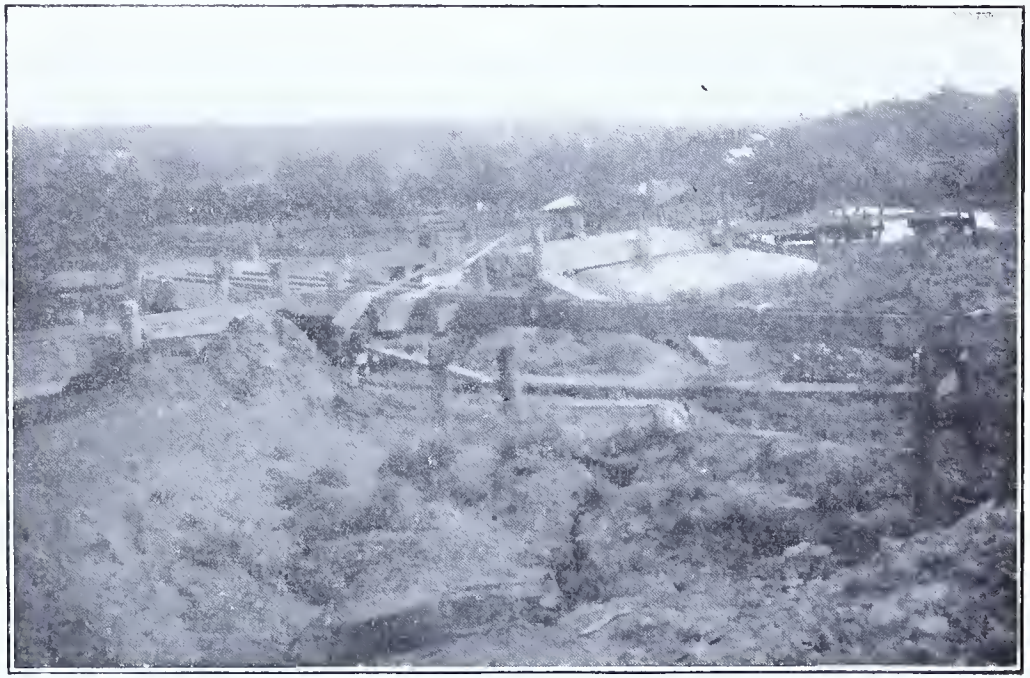


Plate V.—Settling Troughs of Henry Erwin & Sons, Topton.

The two analyses that follow, both of which have been furnished by the proprietors, show the character of the ocher.

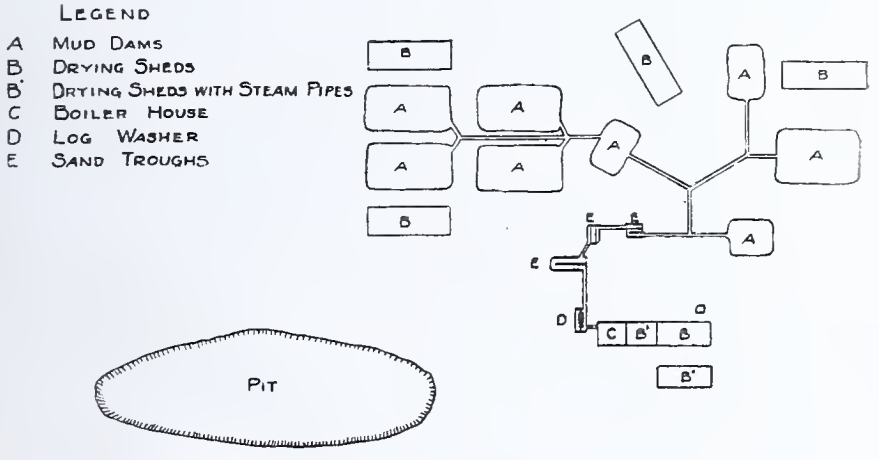
Best Quality Topton Ocher.

SiO_2,	55.50
Al_2O_3,	18.66
Fe_2O_3,	17.49
Combined water,	8.35
	100.00

Second Quality Topton Ocher.

SiO_2,	58.50
Al_2O_3,	20.15
Fe_2O_3,	15.25
Combined water,	6.10
	100.00

The depth of the ocher and clay has not been determined. A 145-foot well near the plant sunk to obtain water for washing the ocher failed to reach the underlying rock.



Scale 200' = 1"

FIG 2 PLAN OF HENRY ERWIN & SONS PLANT. TOPTON PENN.

The ocher removed from the mine is hauled to the washing plant nearby where it first passes through a log-washer, 16 feet in length, to separate the larger particles of iron ore and chert from the ocher. Thence the finer material held in suspension in the water passes through 3 sets of sand troughs, the first about 32 feet long with two compartments, the other two about 16 feet long each with three compartments. It then goes to the mud-dams or settling ponds of which there are 8 holding from 30 to something over 100 tons each of ocher when dry. Enough material is put into these pits to yield a depth

of 2 to 3 feet of ocher after drying. It requires from 2 to 2½ months for the product to dry sufficiently to be dug. Thence it is taken to the drying sheds, of which there are six, ranging from 50 to 75 feet in length and 15 to 20 feet in width. In one there are some steam coils beneath the floor to assist in drying while a small portion of another of the drying sheds next to the boiler house is enclosed on all sides and fitted with a number of steam coils. This holds about 15 tons and is used in winter when air drying is impracticable.

At this plant the greatest obstacle is the small amount of water available for washing the ore. The 145-foot well fitted with a Cornish pump frequently fails to furnish sufficient water. At the time of visit it was only possible to get enough water to wash ocher for from 2 to 2½ hours and then cease pumping for 1 or 2 hours to allow the water to again collect in the well.

The ocher obtained at this plant is hauled to Topton and shipped to the paint mills of the proprietors at Bethlehem where it is ground and either sold as raw ocher or mixed with oil to form paint.

The yearly output of this plant averages 800 to 1,000 tons.

Abandoned Ocher Plant. 3-8 Mile S. of Topton.

Adjoining the ocher plant of Henry Erwin & Sons is another plant that has now been abandoned, the last work being done during the summer of 1908. It was worked by the Atlas Paint Company for several years and later by Reitnauer and Strohl. The first operations were by open-cut but later by a shaft about 35 feet in depth. The ocher was washed in a similar manner to that employed by Henry Erwin & Sons.

Plant of C. K. Williams & Co., 1¼ Miles E. of Fleetwood.

C. K. Williams & Co. operate two ocher mines 1¼ miles E. of Fleetwood which are the largest in the district. When first visited in May, 1909, one of the mines was operated by the Keystone Ocher Company but this was also acquired by C. K. Williams & Co. in February, 1910. Since that time only one mine at a time has been in operation although both may be worked at the same time if necessary. The mines are located on the steep slope of South Mountain about 3-8 mile from a siding of the Philadelphia and Reading Railroad where the finished ocher is loaded into cars for shipment. At the time of the last visit in August, 1911, it was impossible to enter either mine as work had just ceased in one and the foul air had not been drawn from the other sufficiently to render it safe for one to enter. Consequently the descriptions given below are based on the observations taken in May, 1909, when in company with Stoddard and Callen whose results were published by the U. S. Geological Survey* and are here quoted.

*U. S. Geol. Surv. Bull. No. 430, pp. 431-433, 1910.

Plate VI.—Settling Troughs and Drying Sheds of C. K. Williams & Co., Fleetwood.

Plate VII.—Shaft House and Settling Troughs, Fleetwood.

Mine No. 1. This is the mine formerly operated by the Keystone Ocher Company, and lies farthest to the north of the two mines.

"The deposit is opened up through two shafts within 60 feet of each other, one being used as a hoisting and pump shaft and the other as an air and timber shaft. The former is 70 feet deep and extends down to the lower level, from which all the ocher is hoisted. The method of carrying on the underground work is to drift along and follow the pockets and stringers of ocher, mining them out in stopes or breasts, and then to drift indefinitely until other deposits are found.

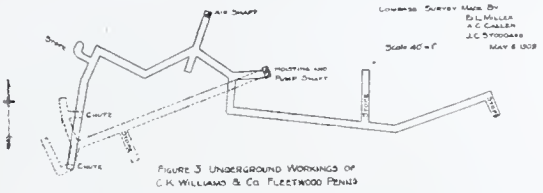


FIGURE 3 UNDERGROUND WORKINGS OF C.K. WILLIAMS & CO. FLEETWOOD PENNA

"The accompanying plan (fig. 3) shows the approximate layout of the underground workings. The drifts or gangways are 6 to 7 feet high and 5 feet wide, being provided with four-piece round timbering to resist the squeezing action of the clay. Lagging of sawed slabs is laid close on the tops and sides, and the bottom is plank floored for the passage of wheelbarrows. Chutes are provided, as shown (fig. 3), for dumping the ocher from the upper to the lower level, whence it is wheeled to the shaft and hoisted. The stopes are turned off where pockets are encountered, and if their size demands it they are timbered up with square sets.

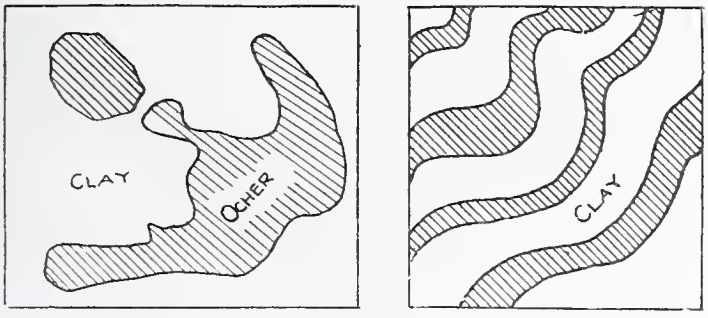


FIGURE 4 SECTION ILLUSTRATING THE OCCURRENCE OF OCHER AT MINE OF C.K WILLIAMS & CO. FLEETWOOD PENNA

"The ocher occurs either as small masses in pockets in the clay, or interstratified with the clay, as shown in the accompanying sketches (fig. 4). It is separated by hand from the clay in the mine, and the clay is used to fill up the old workings. The impurities in the ocher are particles of quartzite, cherty limestone, flakes of shaly limestone,

and fragments and nodules of limonite. The limonite is picked out on the surface and is saved until a sufficient quantity for shipment has accumulated. No bed rock has been encountered in the mine workings, but a well drilled down the hoisting shaft struck loose bowlders of sandstone at 275 feet, which prevented drilling deeper.

"The method of treating the ocher for the market is essentially the same as the methods previously described but the equipment is more complete.

"The ocher is hoisted from the mine by an engine hoist and then dumped into a log washer, from which it passes to a series of 28 floating troughs. These troughs are 14 to 16 feet long and 13 inches square in cross section. The fine sand is separated out in the first 12 or 13 troughs, and the final separation is accomplished in the smaller set of 15, after which the mixture is run through a long trough to the settling ponds. Here it is left to partly dry as a preliminary to its transfer to the drying sheds.

"After it has thoroughly dried in the sheds it is ground in French buhr mills as the final treatment for the market.

"The best sienna from this plant brings from $30 to $40 per ton, and the washed ocher brings $15 to $18 per ton.

"The land is usually leased for a period of fifteen or twenty years, one year or six months being allowed for exploration before the lease is executed finally. A royalty is paid to the owner either at a nominal rate or according to the amount of ocher taken out at a fixed price per ton."

Mine No. 2. The original "C. K. Williams plant adjoins that formerly operated by the Keystone Ocher Company just described and differs very little from it.

"It has been run for five years under the present management, but for the past twenty-seven years it has been worked intermittently, chiefly for the iron ore, which is found in the upper levels and which is now practically exhausted. Old drifts and shafts show that considerable work was formerly done on the property in working out the limonite deposits.

"The present hoisting shaft extends vertically downward 91 feet to the bottom of the lower level and 126 feet to the bottom of the sump, which receives all the mine water and is pumped out at intervals.

"Fifty feet from the main hoisting shaft there is an air shaft 46 feet deep, connecting with the upper level of the mine. The underground workings are similar to those of the other mine, but are larger. The two levels are connected by chutes and by an old shaft which has been retimbered and repaired for the passage of the miners.

"The washing and drying plant consists of a log washer, 26 floating troughs 16 feet long, four mud dams, and four drying sheds.

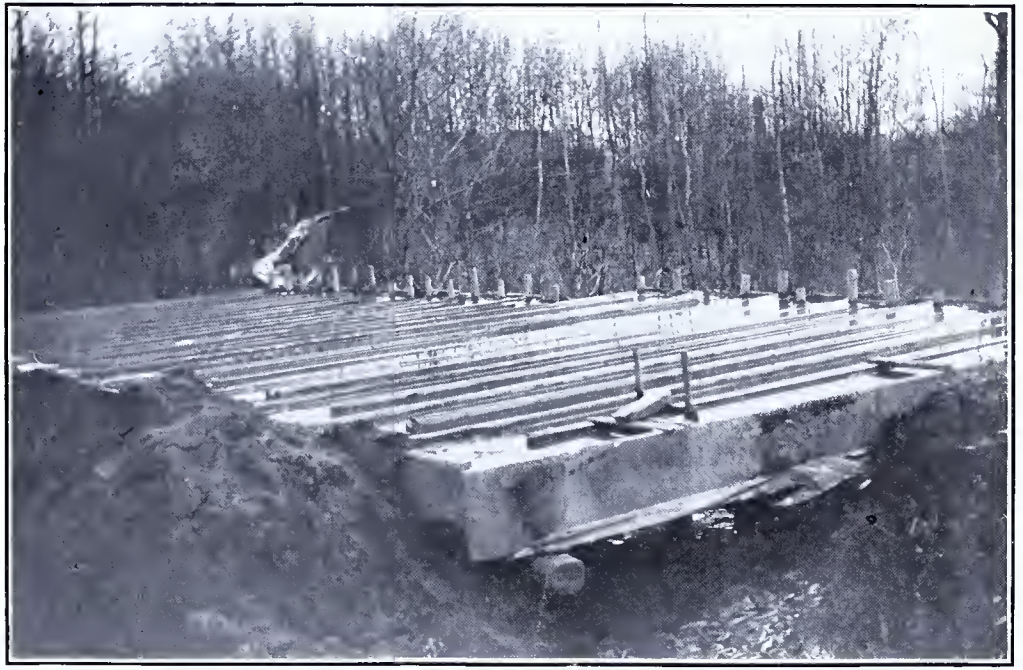


Plate VIII.—Settling Boxes, Fleetwood.

Plate IX.—Settling Pond, Mill, and Drying Sheds, Fleetwood.

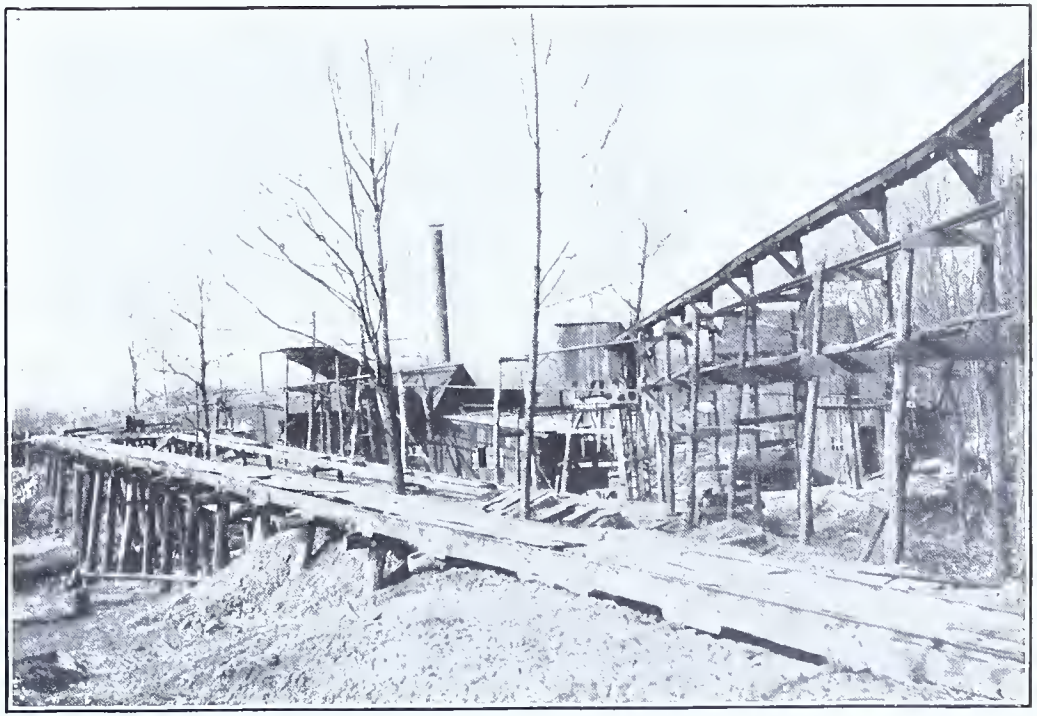


Plate X.—Engine House and Tracks, Fleetwood.

Plate XI.—Removing Partially Dried Ocher from Settling Pond, Fleetwood.

Plate XII.—Drying Sheds Filled with Ocher, Fleetwood.

"The ocher and iron ore occur in pockets, the ore predominating in the upper levels and the ocher in the lower, with clay between. The deposit seems to be in the form of a horseshoe extending along the hill, with its greatest dimension parallel to the hill. The bands of iron ore, clay, and ocher appear to run horizontally. The underlying rock is quartzite, which outcrops along the ridge with a dip of 75° toward the bottom of the hill.

"The ocher found at this mine is of three grades, as follows:

1. "Gold dust," called No. 1, the purest variety.

2. "Gravel ocher," which is good ocher but contains particles of limonite that have to be washed out.

3. Clay and ocher, which is the poorest variety and contains pieces of chert up to 2 feet in diameter. The clay is red, yellow, white and purplish and is of no value.

"The time taken to treat the ocher varies, but in general is takes a month to completely fill the mud dams and three weeks more for the material to dry sufficiently to permit being shoveled. When it has dried to the consistency of a stiff mush it is put in the drying sheds, where it has to be left one month before it is in condition to grind. The material is finished at the company's mills at Easton, Pa."

Since the consolidation a new mill has been erected that will supersede the two old mills formerly used and several new drying sheds are to be built. The new mill is to contain a Sprout-Waldron grinder having a capacity of ten tons per day and it is planned to increase the output to 2,000 to 2,500 tons per year. Steam drying will be abandoned because of the danger of dehydrating the ocher in contact with the steam pipes causing it to become red. Two grades are regularly made the best termed "Gold Dust" and the other "C. L." Still a third of intermediate strength is sometimes produced. According to Mr. Williams the Ferric Oxide (Fe_2O_3) in the Fleetwood ocher varies from 15 per cent to 30 per cent, the balance consisting of Silica (SiO_2), Alumina (Al_2O_3), and water.

Ocher Plant ½ Mile S. of Blandon.

On the property of E. B. Wade, one-half mile south of Blandon, a small amount of ocher has been dug but not recently. Later the mine was worked for the white clay found in association with the ocher. The clay has been used in iron works, as a base for oilcloth, in the manufacture of wall paper, and also for paint. The refined clay used for the latter purpose is said to have been sold for $7.50 a ton. The clay and ocher seem to have been formed from the basal beds of the Cambrian limestone and probably rest upon the Hardyston quartzite. The clay is known to vary from 30 to 50 feet in thickness. It is overlain by 8 to 10 feet of soil and wash material.

Ocher Prospects 1½ Miles S. E. of Blandon.

Some shallow test pits have been sunk on the farms of Lewis Keller and John Hoover, 1½ miles S. E. of Blandon, and ocher has been found. The specimens seen are similar to the ocher obtained at other points as described above. The extent of the deposit is not known.

Ocher Plant ½ Mile E. of Seisholtzville.

Just east of Seisholtzville there is a narrow belt of Hardyston quartzites and possibly Cambrian limestones lying between hills of gneiss. No rocks are seen in place in the valley but loose boulders of quartzite containing *Scolithus linearis* occur in the soil. In this valley several old limonite iron mines have been worked in the past and recently one of these has been reopened by Mr. John D. Reitnauer, Alburtis, R. F. D. No. 2, who has sunk a 45-foot shaft in the bottom of the old open pit which is about 25 feet deep. At the bottom of the shaft he has drifted about 18 feet in one direction and 20 feet in the other and has obtained considerable iron ore but has not saved the ocher. However, in the Spring of 1910 he dug and shipped about 22 tons of ocher from the bottom of the old pit where the washings from an old iron mine had been allowed to settle. This was shipped to Lincoln, N. J., and sold for $2.50 per ton f. o. b. A few years ago some was shipped to Henry Erwin and Sons at Bethlehem.

The mines have been worked at intervals for iron, for ocher, and for both iron and ocher. At one time there was a washing plant here and a kiln where some of the ocher was burned. A portion of the old kiln remains.

Part of the ocher contains considerable manganese and may be considered a low grade of umber while the limonite nodules also show the presence of considerable manganese.

In association with the ocher and iron ore there is considerable white clay. In one place this clay is said to be 26 feet in thickness and some of it has been dug and shipped to potteries in Norristown and Chicago.

Plant of C. K. Williams and Co., 1 Mile N. W. of Reading.

On the west side of the Schuylkill River, one mile N. W. of Reading, is an ocher mine formerly worked by the Keystone Ocher Company but recently acquired by C. K. Williams at the same time that the plant at Fleetwood was purchased. Several shafts have been opened near the bottom of a small valley and as the water drains toward the shafts there has been considerable difficulty in keeping the works free from water. When visited in August, 1910, one shaft only was in operation and little ocher was in sight. The shaft, which is 70 feet deep, seems to be in the bottom of a solution hole in the limestone and when a drift was run off in one direction a ledge of limestone was encountered with only a small amount of ocher in the enlarged joint planes.

Plate XIII.—Plant of C. K. Williams & Co., Reading.

The ocher from this region contains less limonite iron ore than in most places but considerable chert. Some of the best ocher of the district has been mined here, part of which ranging in ferric oxide (Fe_2O_3) from 68 per cent to 72 per cent is really a sienna as it has been generally called. Some of it on the other hand runs as low as 35 per cent. of ferric oxide.

The equipment consists of a boiler and engine house, a log washer, settling troughs, tanks of the usual kind, a drying shed, a mill for grinding, a small roasting furnace where some of the ocher is burned when there is a demand for it in that condition. Most of it, however, is shipped as raw finished ocher. The ocher is hoisted to the furnace in a bucket operated by the engine. The drying shed is 70 feet long by 10 feet wide and contains 8 shelves 10 inches apart, on which the ocher is placed to dry on its removal from the settling ponds.

The operations in this region seem to have been extensive but in the absence of any record of former operations the true condition of the deposit is uncertain. Recently a drift broke into old workings that were not known to exist.

Other Occurrences of Ocher in Pennsylvania.

Although ocher is not being mined in the State outside of the Easton-Reading district at the present time, deposits are known to occur at many places, some of which have been worked in earlier periods. It is impossible to obtain information concerning all of these and there is no doubt but that this report is incomplete in that many are not mentioned.

Abandoned Ocher Mine ½ Mile S. W. of Stouchsburg, Berks County.

Ocher and limonite iron ore have been mined one-half mile S. W. of Stouchsburg, Berks County, on the farm of Hiester Filbert of Robesonia. Many years ago there was an extensive open cut brown iron ore mine operated on the adjoining farm of Thomas W. Reed. That mine was abandoned long ago and about 25 years ago an iron mine was opened on the Filbert farm and the material from the washery was run into the Reed pit. Ten to 12 years ago the ocher in this pit was found to have considerable value and it was dug for paint while the mine was reopened for ocher and the limonite considered the by-product. A plant for washing, drying, and grinding the ocher was erected and several car loads of finished product were shipped to Lebanon, Reading, and Philadelphia. Ruins of the mill foundation still remain.

In the Summer of 1907 a 45-foot shaft was sunk in the same region and a good grade of ocher found but none was shipped. The ocher, iron ore, and associated clay are found on the surface of Silurian limestones and represent decomposition products.

Ocher Near Old Zionsville, Berks County.

Ocher is said to have been mined at one time on the farm of Mr. Schuchert, one-half mile from Old Zionsville. No other details are known.

Ocher 1 3-4 Miles W. of Saylorsburg, Monroe County.

The following quotations are from I. C. White's Report on The Geology of Pike and Monroe Counties.*

"Much ocher is found interstratified with the iron ore at the last locality, (iron mine $1\frac{3}{4}$ miles west of Saylorsburg) a specimen of which yielded the following:

Silica,	57.400
Alumina,	19.033
Sesquioxide of iron,	10.107
Lime,	0.100
Magnesia,	1.740
Water,	6.458

"The origin of these ores and ochers seem to be closely connected with the disintegration of the great Oriskany sandstone, just above (north of) them.

"The ochre beds certainly originated by the removal of lime solution from the layers of the impure Stormville limestone, in fact it is a common thing to see a coating of ochre adhering to the weathered outcrops of many of the limestone layers in No. VI; so that it is possible the iron in the ochre analyzed represents only that already in the rocks previous to removal of the lime.

"The ochre is of a dull yellowish color, and could possibly be used in the manufacture of mineral paints, though no tests for that purpose have ever been made."

The section passed through in sinking a shaft is given as follows:

	Feet.
Sandy ochre,	10
Iron ore, somewhat sandy,	12
Ochre,	5
Iron ore "Bomb-shell,"	3
Ochre,	$1\frac{1}{2}$
"Bomb-shell" ore,	4
Sandstone,	?
	$35\frac{1}{2}+$

*Sec. Geol. Surv. of Pa., G 6, pp. 139, 140, and 293. 1882.

Ocher in Lancaster County.

Persifor Frazer, Jr., in his Report on the Geology of Lancaster County* makes the following statement in describing the Mylin iron ore mine in the southeastern corner of Pequea Township: "A brilliant orange colored ochre is interspersed among other impure iron hydrates to a greater degree than in other similar dump piles." There is little question but that ocher could be obtained from old mud-dam deposits in that section similar to those that have been utilized in the Easton-Reading district, and probably deposits of ocher occur associated with the iron ore in such condition as to justify their operation for ocher with the iron ore considered as a by-product.

Ochers of York and Adams Counties.

That the brown iron ores of the limestone valleys of York and Adams counties are associated with ochers would be expected. Frazer in his Report on the Geology of York and Adams Counties† refers to the associated yellow clays in several places and in one place (p. 61) in describing E. Halderman & Co.'s iron ore mine lying $3\frac{3}{4}$ miles northeast of Hanover, says: "The external characteristics of the ore were those of a sandy limonite full of seams of ocher, and containing "göthite and other oxides of iron."

*Sec. Geol. Surv. of Pa., C 3, p. 237, 1880.
†Geol. Surv. Surv. of Pa., C, 1876.

CHAPTER III.

UMBER.

Much of the ocher of the limestone valleys of Pennsylvania contains small amounts of manganese oxide while almost every analysis of limonite iron ore shows its presence. Under these conditions it seems rather strange that few localities are known where the percentage of manganese is great enough for the mixture to be called umber. Only three localities are known to the writer where deposits of umber of sufficient size to justify working occur. Of these two have been operated at intervals for many years while the other has only been prospected.

Umber Deposits at Quaker Hill, Northampton County.

On the south slope of Quaker Hill, or Camels Hump, about 2½ miles north of Bethlehem, there is a deposit of umber that was formerly worked by Henry Erwin & Sons but at present owned and operated by C. K. Williams & Co. The deposit has been worked in a small way for more than 25 years. It is worked in shallow open pits. The following section at one side of the pit is typical although a different arrangement of the materials may be found 10 feet distant.

	Feet.
Soil and hillside wash, ...	3
Reddish-brown clay, ...	1½
Light-yellow ocherous clay, ...	5
Darker-yellow ocherous clay, ...	½
Dark-brown umber (base not exposed), ...	6
Total, ...	16

In one place a pit was sunk to the depth of 48 feet but in most places the umber does not extend that far. White and yellow clay are said to lie beneath the umber bed.

In the layer of hill-side wash are many angular pieces of gneiss that have been washed from the small hill of gneiss that lies to the north and that has reached its present position by a strike fault along the north side of the hill. Within the bed of umber there are occasional layers and pockets of yellow ocher some of which are as much as 14 inches in thickness. The umber bed further contains many small pieces of vein quartz, iron ore fragments, and limonite geodes filled with drab clay. These impurities are more abundant in the upper portion.

Plate XIV.—Open Cut Umber Mine, Quaker Hill.

The umber and associated materials represent the decomposition and replacement products of the Hardyston quartzite which extends along the south flank of the hill as determined by the float rock. The umber deposit also contains some pieces of the quartzite that have resisted decomposition.

The umber is shipped to Easton where it is washed and ground. It commands a price of $18 to $20 per ton when finished.

Umber Deposit, 5 Miles E. of Doylestown, Bucks County.

This deposit, which has not been worked for many years, is described by B. S. Lyman in his Report on the New Red of Bucks and Montgomery Counties* as follows: "A deposit of umber or dark ferruginous earth occurs on the south side of Buckingham Mountain, near the road-forks, where the road crosses the gap in the middle of the mountain, between Pineville and Centreville. A hole about three feet in diameter and said to be about 30 feet deep was dug there, but had quite fallen in when visited in 1889. It was first dug about 1850, but was renewed about 1885. The umber is said to have been darker and purer towards the bottom. Traces of it are said to have been found in a line for about a quarter of a mile southward; but none northward. The place appears to be just inside the Paleozoic rocks, here the Chikis (Hardyston) Sandrock, and the traces found southward are probably merely superficial ones carried in that direction by the surface waters. The extent of the deposit is not likely to be very great, but cannot be estimated without more digging." The deposit occurs along a fault by which the Cambrian quartzite and limestones have been brought up and agrees with the explanation previously offered to account for certain brown iron ore and ocher deposits.

Umber Deposit 1 Mile W. of Bethel, Berks County.

A deposit of umber has been prospected one mile W. of Bethel, Berks County, on the farm of Dr. W. C. Kline of Myerstown. It occurs as a surface deposit resting upon a brecciated chert rock and has been formed by the decomposition of sandy layers of the Martinsburg formation. Manganiferous material has been observed by Dr. Kline extending eastward along the strike of the beds for a distance of about three miles. Several test pits have been sunk and umber discovered in all at a depth of from 3 to 8 feet. The umber possesses a dark brown color, is comparatively free from impurities and is said to have been examined by paint manufacturers who have stated that it was of good quality. Owing to the fact that the deposit is remote from any railroad, the nearest shipping point being Myerstown, 8 miles distant, it has not been developed and none has been shipped.

*Sec. Geol. Surv. of Pa., Summary and Final Report, p. 2633, 1895.

CHAPTER IV.

SIENNA.

As previously stated there is no sharp line between ocher and sienna as materials occur in nature showing all gradations between the two. The term sienna is properly applied, however, only to those pulverulent substances whose composition is practically that of high grade limonite iron ore. With an increase of alumina (Al_2O_3) and silica (SiO_2), sienna passes into ocher or with an increase of those substances and manganese oxide (MnO_2) it grades into umber.

With the exception of part of the material obtained at the ocher mine of C. K. Williams & Co. one mile N. W. of Reading, there is only one locality in Pennsylvania where sienna is being worked at present.

Sienna Mine on Neversink Mountain, Reading.

On the north slope of Neversink Mountain, directly south of the east part of Reading, and about 100 feet from the crest of the mountain, sienna has been obtained for several years.

Neversink Mountain, and its counterpart, Mt. Penn, are composed of Hardyston quartzite which being resistant to the atmospheric agencies, has been reduced more slowly than the adjacent limestones and so form steep hills or mountains rising 600 to 800 feet above that portion of the valley in which the city of Reading is located. Notwithstanding the fact that it has worn away slowly, at the present time a considerable thickness of greatly decomposed rock occurs on the slopes and many sand pits are located here. Part of the rock is decomposed to such an extent that it can be readily crumbled in the hand, particularly those beds in which arkose is a prominent constituent, while all is rotten enough to be easily crushed in a rock crusher. While working one of these sand pits on land owned by the Michael Haak estate about 8 years ago a layer of sienna was struck interbedded with the rotten quartzitic sandstone. The true character of the material was not recognized at first and it was ignored. On learning, however, that the product was a high-grade sienna drifts were run on the bed in either direction and work has been continued somewhat intermittently ever since.

At one time C. K. Williams & Co. operated a mine on the hill but for several years the only operations there have been carried on by Mrs. John P. Lance of Reading, who is one of the heirs to the property. Most of the time only a few men have been employed and the total yearly output varies from 125 to 200 tons. When

visited in August, 1910, two men only were engaged in the mining. It is said that C. K. Williams & Co. have recently taken a lease on an adjoining property and plan to open a mine.

The sienna posseses a rich yellow color with thin streaks of somewhat darker materials running through it. It is remarkably free from impurities of any kind. The following analysis is furnished by Mr. C. K. Williams.

Fe_2O_3,	69.0
SiO_2,	24.0
Al_2O_3,	3.0
Combined water and undetermined properties,	14.0
	100.0

The ore has the same dip as the enclosing beds of rotten quartzite, 25° to 30° N., which is about the same as the slope of the mountain. It represents a replacement of the quartz and arkose of certain beds and shows the stratification lines of the original rock. These lines show even more distinctly in the rich yellow fine grained sienna than in the unaltered coarser quartzite. The replacement has not taken place with much regularity as the ore is as much as 5 feet thick in some places and rapidly thins to a few inches or entirely disappears within 10 to 15 feet. The strata of the quartzite, on the other hand, are remarkably regular showing that the sienna does not represent a single stratum of the original rock. The thickening and thinning of the ore bodies occur both in the direction of the dip as well as along the strike of the quartzite. However, certain layers seem to have been replaced to a greater degree than others and when ore is found the drifting is carried along the same strata even though the ore may be entirely lacking in certain places.

Two bands or series of beds carrying the sienna have thus far been found but it is not improbable that more may be located.

On account of the small bodies of ore and the uncertainty of its continuation, mining is done in a rather primitive manner, practically without equipment. The present workings consist of a tunnel run into the mountain about 35 feet to the place where the ore was encountered. The drift was then turned along the strike about 20 feet, part of which was in ore. At the end of this drift a pocket of good ore being found in the bottom an underhand stope was opened along the dip. This stope was about 10 feet in depth. The ore is taken from the mine by wheelbarrows and is partially dried by being placed on a sheet iron platform beneath which a wood fire is kindled. It is then placed in a covered storage shed from whence it is hauled to the railroad at Reading for shipment. The price obtained is about $20 per ton f. o. b.

CHAPTER V.

CARBONATE OF IRON PAINT ORES OF LEHIGH GAP.

The paint ores of the Lehigh Gap region outcrop in a narrow band along the north side of Stony Ridge, which is a rugged ridge of resistant Oriskany sandstones broken through in a few places by the streams of the region. The ores have been successfully worked in a belt extending almost entirely across the southern end of Carbon County from Germans to Little Gap.

These are of special interest because they have been worked longer than any other paint ores of the State and the output exceeds in value that of any other paint ore district of the State. They have been mined continuously since their discovery in 1856.

In chemical composition also they are unique as no ores of this character are known elsewhere. The product produced is known in the trades as Prince's Metallic Paint and Prince's Double Label Mineral Brown and possesses especial value for the painting of metallic structures.

HISTORY OF THE DEVELOPMENT OF THE REGION.

The discovery of the paint ore of the region dates back to 1856 when Mr. Robert Prince found an outcropping rock containing considerable iron a short distance northeast of the present town of Hazard and near the crest of "Stony Ridge," where it is crossed by the wagon road. The ore was discovered at one of the very few places in the region where it appears at the surface. The proximity of the bed to the resistant ridge-making Oriskany sandstone causes it to be almost invariably concealed from view at its outcrop by the accumulation of talus and but for the absence of the talus at this point the ore might have long remained undiscovered unless some excavation had accidentally revealed its presence. An examination of the rock by Mr. Prince seemed to indicate its value for the manufacture of metallic paint and an analysis confirmed that belief. He at once began to work the deposit, grinding it at a mill which he owned on Big Creek and hauling the finished product to Weissport where it was shipped. It brought $120 a ton f. o. b. at Weissport which left a considerable margin of profit, even though the mining, milling, and hauling were expensive. The occurrence of the ore in a definite continuous bed led others to search for it with the result that in a short time there were many other competitors operating in the region. The operations were soon extended along the entire southern end of Car-

bon County and a short distance into Schuylkill County. Shafts were sunk on the outcrop and tunnels were driven into the ridge from either side and so extensive were the workings that it is now possible to trace the ore bed by the almost continuous line of sink holes and abandoned shafts. For many years various companies operated mines but the poor character of the ore in certain places and the keen competition gradually eliminated most of the companies and for many years the industry has been represented by two companies only. These are The Prince Manufacturing Company, which is the successor to the original plant of Robert Prince, the discoverer of the ore, and the Prince Metallic Paint Company, successor to the firm of Rutherford and Barclay. These two companies largely control the output through the options which they hold on other properties than those they are now working. The Prince Manufacturing Company with offices in New York City operates mines in the vicinity of Hazard and kilns and a mill for roasting and grinding at Bowmanstown, while the Prince Metallic Paint Company with offices in Allentown operates mines about 1½ miles east of Millport and has its kilns and a mill at Lehigh Gap.

Besides these two companies a third has recently started at Little Gap. As yet no ore has been shipped from this mine, although considerable has been taken out. This company is controlled by William G. Freyman.

GEOGRAPHY.

The paint ore occupies a definite position with reference to the topography of the region. North of Blue or Kittatinny Mountain, which extends across New Jersey from the Shawangunk Mountains of New York to the Schuylkill River and represents the southeastern range of the Appalachian Mountains there is a secondary ridge of resistant Oriskany rocks of somewhat lower elevation lying parallel and at a distance of about one mile that has received the name of Stony Ridge or Devil's Wall. This ridge is similar to Blue Mountain in that it controls the drainage and is cut through by streams in only a few places forming water gaps. The Lehigh River cuts Stony Ridge about one-half mile south of Bowmanstown and has dissected Blue Mountain at Lehigh Gap. Stony Ridge is a single ridge except from Bowmanstown to Hazard where it is double owing to the repetition of the Oriskany ledge due to faulting. The paint ore lies to the north of these sandstone ridges except for about 1½ miles in the vicinity of Hazard where it lies to the south of the second ridge. The explanation for this condition will be given in the discussion of the structure of the region.

Between the two ridges of resistant siliceous rocks lies a longitudinal valley cut in the more easily erodable shales and limestones. This is occupied by the Aquashicola Creek which flows from the east to join the Lehigh River at Lehigh Gap and Lizard Creek which comes from the west and empties into the Lehigh a short distance below Bowmanstown. The Lehigh River itself flows in this valley for about two miles from the point where it cuts through Stony Ridge to Lehigh Gap. This valley has been largely filled with glacial debris brought down by the Aquashicola Creek and by the talus from the ridges of resistant rock that bound the valley.

North of Stony Ridge the country is rolling with many hills and valleys and with streams in general parallel to the strike of the formations though not universally so.

Until recently the region was primarily devoted to agriculture in the valleys while the rocky ridges furnished considerable timber. The New Jersey Zinc Works now have an extensive reduction plant on the flood plain of Lehigh River at Hazard and have built the town of Palmerton which has a population of 2,000. Bowmanstown is the only other town of consequence in the district.

Two main lines of the Lehigh Valley and Jersey Central railroads following the Lehigh River cross the district while the Lizard Creek branch of the former follows the valley of Lizard Creek westward and a narrow gauge line runs eastward from Lehigh Gap to Kunkletown. Thus good shipping facilities are available for the products of the region.

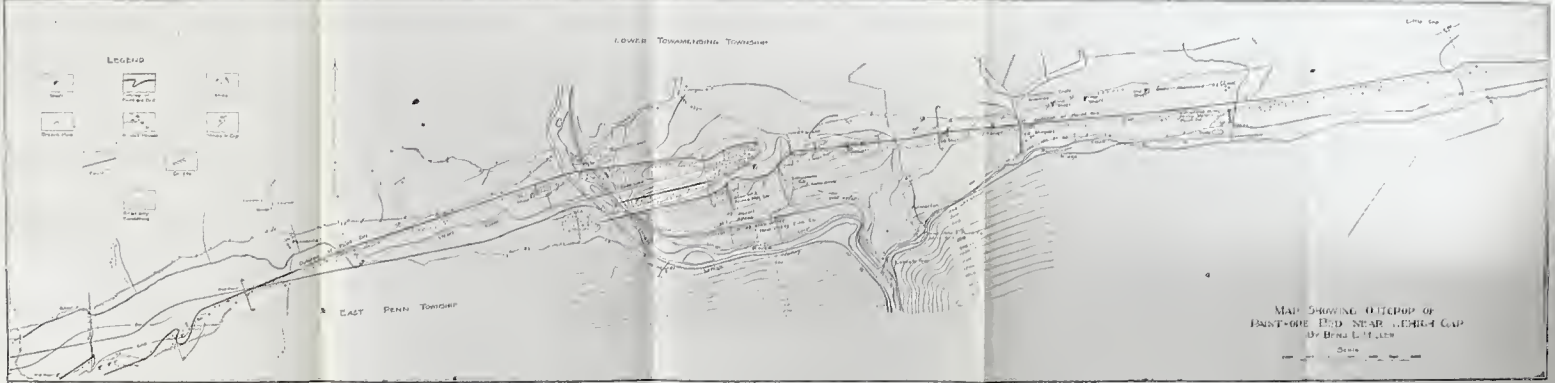
GEOLOGY.

The rocks of the region belong to the Silurian and Devonian systems. The columnar section is as follows:

System.	Period.	Formation.	Character of Rock.	Thickness in Feet.
Devonian,	Onondagan series.	Marcellus? and Hamilton.	Black shales,	2,500
		?	Hydraulic cement,	20 to 50
		?	Paint ore,	2 to 4
		Esopus,	Siliceous shale and clay	4 to 10
	Helderberg series.	Oriskany,	Sandstones,	150 to 175
			Shales,	210 to 300
		?	Limestone with some shales,	660
Silurian,	Salina.	Aquashicola,	Red and olive colored shales,	1,275
		Shawangunk,	Coarse sandstone and conglomerates,	1,125

The Shawangunk Formation.

The Shawangunk formation consists of quartzites and siliceous conglomerates that form the Blue Mountain of Pennsylvania and its continuation, the Kittatinny Mountain of New Jersey, and Shawangunk Mountain of New York. These names have been used in the


LEGEND
LOWER TOWAMENSING TOWNSHIP
EAST PENN TOWNSHIP
MAP SHOWING OUTCROP OF
PAINT-ORE BED NEAR LEHIGH GAP

different states for the continuations of the same range. The formation receives its name from the last named portion of the range. The strata now included in this formation were formerly classified as the Oneida and Medina formations and as such they are described in the various reports of the Second Pennsylvania Geological Survey. Recent investigations in New York have shown the presence of an eurypterid fauna of Salina age thus proving the much more recent age of the beds. Although no fossils have thus far been reported from this formation in Pennsylvania there is no doubt of its stratigraphic continuation with similar strata carrying the Salina fossils at Otisville, New York.

The Shawangunk formation consists primarily of a conglomerate in which small quartz pebbles are cemented together by siliceous material. Certain layers are very fine grained, passing into a quartzite while occasionally strata are observed in which the pebbles are fully an inch in diameter. The resistant character of the rocks of this formation are shown by the high ridge formed by the outcropping beds. This formation is well exposed in Lehigh Gap where it has a thickness of about 1,125 feet. It dips steeply to the north beneath younger beds and does not reappear at the surface.

The Aquashicola Formation.

Immediately overlying the Shawangunk formation and dipping steeply to the north is a considerable thickness of red and olive colored shales with occasional layers of sandstones that are well exposed in the isolated round hill just north of Lehigh Gap station. These shales are known in the reports of the Second Pennsylvania Geological Survey as the Clinton shales. It was believed that they represented the iron-bearing Clinton formation of New York and Central Pennsylvania and much search was made for fossil iron ore in these shales between the Delaware and Susquehanna rivers. The position of the beds overlying strata of Salina age proves them to be of much more recent age.

The red shales overlying the Shawangunk conglomerate in this vicinity are believed to represent the same horizon as the red shales occupying the same position in Ulster County, New York, to which the name High Falls has been applied. In the Franklin Furnace folio of the U. S. Geological Survey the rocks of Kittatinny Mountain, formerly called Medina, are considered the equivalent of the High Falls of New York, so it seems best for the present to apply a new name to these shales and the present name is chosen because of the occurrence of the shales in the valley of Aquashicola Creek.

The shales are red in most places but occasional layers are of olive color. Sandstone layers are numerous in the lower part of the formation but are rare in the upper portion.

The Aquashicola shales are much less resistant than the siliceous Shawangunk and Oriskany formations so have been worn away rapidly and their outcrop determines the location of the valley occupied by the Aquashicola and Lizard creeks. For this reason they are exposed in few places. The flood-plain deposits of both streams tend to obscure them as well as the talus from the ridges on either side.

The Aquashicola strata dip to the north. Their combined thickness is estimated to be about 1,275 feet.

The Helderbergian Series.

Above the High Falls formation in the vicinity of Lehigh Gap is a considerable thickness of limestones and shales that are poorly exposed and that as yet have not been studied carefully enough to warrant their separation and correlation. White in his report on the Geology of Pike and Monroe Counties* divides the series into the following members:

	Thickness.
Stormville shales,	160 feet
Stormville conglomerate,	15 "
Stormville limestone,	145 "
Stormville hydraulic cement bed,	10 "
Decker Ferry limestone,	20 "
Decker Ferry sandstone,	25 "
Decker Ferry shale,	15 "
Bossardville limestone,	40 "
Poxono Island shales,	225 "
Poxono Island limestone,	5 "
Total,	660 feet

Several of the above members contain fossils so that it will no doubt be possible to establish correlations with the New York formations with more detailed study.

In New Jersey the strata lying between the Longwood (High Falls) and Oriskany formations are divided into the following members of Weller.†

Devonian	Thickness.	
Kingston beds,	80 feet,	correlated with
Becraft limestone,	20 "	Stormville
Stormville sandstone,	?	shales.
New Scotland beds,	160 "	
Coleymans limestone,	40 "	

*Second Geological Survey of Pennsylvania, Report of Progress G 6, 1881.
†Geol. Surv. of New Jersey, Report on Paleontology, Vol. III. The Paleozoic Faunas. 1903.

Plate XVI.—North Side of Stony Ridge Showing Vertical Beds of Oriskany Sandstone.

Silurian.

Manlius limestone,	35 feet
Rondout formation,	39 "
Decker Ferry formation,	52 "
Bossardville limestone,	100 "
Poxono Island shale,	?
Total,	526+ feet.

Oriskany Formation.

The Oriskany formation consists of sandstones and conglomerates of resistant character that are responsible for Stony Ridge. The formation is divisible into two portions, an upper member composed of coarse sandtone or conglomerates and a lower portion of quartzitic shales resembling flint in appearance.

The Oriskany shales are much less homogenous than the overlying sandstone. In the Kline tunnel of the Prince Manufacturing Company at Hazard the following strata of the Oriskany shales were penetrated:

	Feet.
Flint,	45
Red clay,	1
Black clay,	9
Hematite iron ore,	1
Clay containing chert fragments,	3
Sandstone,	24
Clay and flint,	72
Fine sandstone,	2
Clay and flint,	30
Sandstone,	4
Flint,	20
Total,	211

In some other places the lower member of the Oriskany has a thickness of about 300 feet.

The flinty quartzite of the shales contains many fossils although it is seldom possible to remove them from their matrix.

The sandstones and conglomerates vary in thickness from 150 to 175 feet. The cementing material is mainly calcareous and its removal in many places has cauesd the rock to disintegrate. Sand quarries are abundant all along the ridge for many miles, the material being shipped to many points in the State for use as molding sand, for fire brick, concrete, and other purposes, the silica fre-

quently running as high as 98 per cent. In working the sandstone for sand the places where the rock is most greatly decomposed are selected and little crushing is required. The sand grains are usually well rounded. The color is white to light yellow.

The Oriskany sandstone in Stony Ridge has a steep dip almost everywhere and not infrequently is overturned to the south as much as 15° to 20°. The steep dip is responsible for the jagged character of the ridge. Fossils are not numerous but specimens of *Spirifer arenosus* and a large species of coral have been observed in many places while occasional specimens of other species occur sparingly.

The Oriskany sandstone is greatly jointed and in certain places it is extremely difficult to distinguish between the joint and bedding planes. One of the prominent joint plane directions which is present generally throughout the region has a dip of 40° to 50° to the south and seems to be responsible for the greater number of Oriskany boulders on the south side of the ridge.

Onondagan Series.

Overlying the Oriskany sandstone are three beds of distinct lithologic character. They seem to represent the Onondagan series of New York although exact correlations have not been made. Immediately above the Oriskany is a bed of plastic clay varying in thickness from 4 to 10 feet and ranging in color from white to yellow, to red, to blue. In places it passes into a sandy shale and some loose specimens found on the north side of Stony Ridge near the outcrop of this bed and supposed to come from it showed the typical cockscomb markings so characteristic of the Candagalli or Esopus grit of New York.

Next in order is the paint ore bed which will be described in detail in a later section.

Overlying the paint ore is a layer of cement rock with a thickness of 20 to 50 feet. The usual thickness is about 25 feet. The lower 20 feet of the cement bed consists of hard, compact blue rock closely resembling the paint ore but containing more calcium carbonate and less iron. It is very fine grained and contains small veins of quartz and calcite. It does not show the slaty cleavage which is so characteristic of the cement rock of the Lehigh district. The upper 5 feet of the cement rock consists of a cherty limestone, the chert black in color and in the form of nodules. The cement rock contains many fossils, most of which, however, are considerably crushed. The following forms were determined by Dr. J. M. Clarke, to whom a small collection was sent by the writer: *Leptaena rhomboidalis*, *Orthis* sp., *Meristella* sp., *Streptolasma* sp., *Fenestella* sp., *Phacops rana.*, *Dalmanites* sp.

Plate XVII.—Crest of Stony Ridge, West of Bowmanstown.

The cement rock was formerly burned and it is said to have produced a very good cement. It was used in locks of the Lehigh Canal and other structures and their durability have proved its worth. The small thickness of the bed and the difficulty of working it prevent it from being utilized now in competition with the cement rock on the other side of Blue Mountain.

Marcellus (?)-Hamilton Series.

Overlying the Onondagan series is a great thickness of black fissile shales which have been penetrated in several places by tunnels driven to the paint ore on the north side of Stony Ridge. In some places the amount of carbonaceous matter present has caused certain persons to believe that the strata contained coal. Several thousand dollars were expended in developing a so-called "coal mine" in these beds near Kunkletown but without success. The lower part of the black shales in the region studied are barren of fossils but in the vicinity of Bowmanstown Hamilton fossils are abundant.

Phacops rana is one of the most common forms. The total thickness of these beds as determined by the Second Pennsylvania Survey is about 2,500 feet. Although earlier workers in this district have divided the strata here discussed as a unit into two formations, the Marcellus and Hamilton, it is a question whether the division is justifiable as the separation line is certainly very indistinct in most places.

Description of the Paint Ore.

Distribution.—As stated in the introduction and as shown on the accompanying map the paint ore outcrops in a single line from a point one mile west of Germans to Bowmanstown, in three bands from there to a point opposite Lehigh Gap, and again in a single band eastward to Little Gap. The formation of which the paint rock forms a part has a much greater extent but the peculiar lithologic characteristics that render the rock valuable for paint are wanting except in this limited area. Much prospecting has been carried on west of Germans and east of Little Gap but with indifferent success. About three-fourths of a mile east of Little Gap a tunnel was run into the hill at considerable expense in the hope of locating the paint rock but the project proved a failure and the mill that was erected at that place proved to be useless for many years. Recently, however, it has been used for the preparation of some of the ores mined at Little Gap. West of Germans the paint ore has also been proved to be either absent or of poor quality. The best ore seems to occur east of the Lehigh River, between Hazard and Little Gap and the most extensive workings have been carried on near Hazard and in the vicinity of Millport.

Lithologic Characters.—The ore resembles an impure blue limestone but without distinct bedding or joint planes, and were it not for the high specific gravity it would scarcely be thought to possess any value. It is dark blue in color when fresh but on being exposed to the air soon reddens due to the oxidation of the iron originally present in the form of the carbonate. Specimens of ore are frequently found about old workings that are red throughout, all the iron having been oxidized to the ferric state. It is called "sunburned ore." Some specimens that had been kept in the office of the Prince Metallic Paint Co. at Lehigh Gap for several years were also reddened throughout and had been weakened so much by the change that they were very readily broken.

In many places there is no sharp line of separation between the paint ore and the overlying cement rock and the miners distinguish them chiefly by means of the greater weight of the ore. Elsewhere the ore breaks in a different manner than does the cement rock and the miner can distinguish them in that way.

The ore in many places contains considerable pyrite and usually the most pyritic portions of the ore are deficient in fossils. The ore obtained from the Kline tunnel of the Prince Manufacturing Co. near Hazard and that mined at Little Gap carries little pyrite. Those specimens that carry most pyrite are very tough and require considerable effort to reduce them to the size desired for burning.

The specific gravity of the ore varies from 3.2 to 4.

Paleontologic Character.—Fossils occur in the paint ore in many places and in certain localities they are so abundant that they constitute as much of the ore as the matrix in which they are enclosed. In general, they are greatly distorted due to the crushing which the rock has undergone subsequent to its deposition. Dr. J. M. Clarke has recognized the following species:

Gyroceras matheri
Leptaena rhomboidalis
Atrypa reticularis
Atrypa sp.
Orthis sp.
Meristella sp.
Spirifer sp.
Rhipidomella sp.
Liorhynchus (?) sp.
Fenestella sp.
Hindia sp.
Dalmanites selenurus (?)

Chemical Composition.—The most complete analysis of the hard product available is one made by Mr. A. S. McCreath, while chemist of the Second Geological Survey.* It is as follows:

Metallic iron,	34.600
Metallic manganese,	.929
Alumina,	5.492
Lime,	3.510
Magnesia,	1.081
Sulphur,	.674
Phosphorus,	.018
Silica,	16.210
Loss on roasting,	24.350

In discussing the analysis Mr. McCreath says: "In the raw ore the elements exist for the most part as carbonates."

Thickness.—The ore bed is of variable thickness but averages somewhat less than 2 feet throughout the district. The greatest thickness observed was 2 feet 8 inches but the ore has been reported to have been almost 4 feet thick in some of the abandoned workings. Such reports could not be verified, however.

The ore has been found in two thin bands separated by a thin layer of shale or clay in many places. An example of this occurred in the old drift, of the Prince Manufacturing Company where the following section was taken.†

Cement.	Feet.	Inches.
Blue clay,	0	6
Paint ore,	1	0
Soft slate,	0	3
Paint ore,	0	6
Soft slate,	0	4
Clay and soft slate.		

Structure.—The paint ore bed has undergone many changes since its deposition in the Devonian sea by which its original position has been greatly altered. It now forms a part of the Appalachian Mountains, which are the result of uplifting accompanied by folding and faulting that occurred at the close of the Paleozoic era. Open, closed, and overturned folds, and normal faults all are represented in this region and have had their effect in producing the present structure

*Second Pennsylvania Geological Survey, Annual Report, 1886, Pt. IV, p. 1404.
†Second Pennsylvania Geol. Surv., An. Rep. 1886, pt. IV, p. 1396.

of the paint ore bed. At the William G. Freyman mine at Little Gap the ore body where worked has a northerly dip of 75° to 85° and forms the south limb of a sharp synclinal fold. Proceeding westward to the mine now being operated by the Prince Metallic Paint Co., which is about $1\frac{3}{4}$ miles east of Millport, the ore bed has a dip of 80° to 85° to the south showing it to be part of an overturned fold.

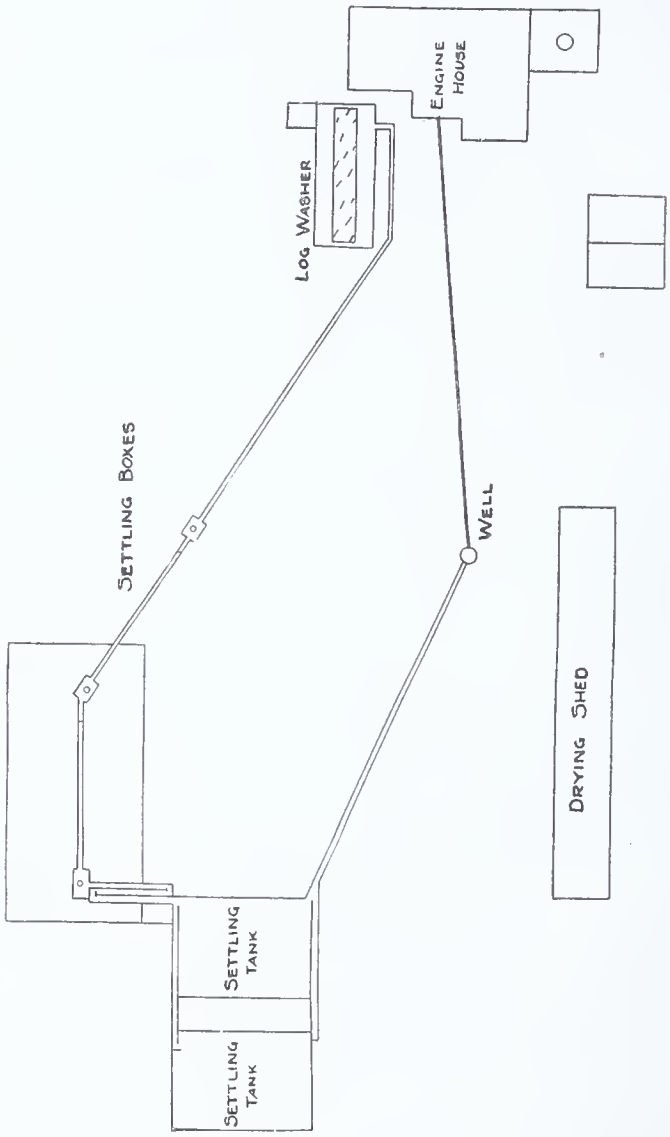


FIGURE 5 PLAN OF C. K. WILLIAMS & CO. PLANT READING PENN.

This overturning is more pronounced farther west and about one mile east of Millport has a dip of 48° in a tunnel formerly worked by the Prince Manufacturing Co. About one mile west of Millport in what was called Mine No. 2 of the Prince Manufacturing Co. the syncline is again normal and the ore stratum dips 79° N. One-half mile farther west and across the road from the school it is 68° N.

and varies from 62° N. to 72° N. to the next road that crosses the divide. It then flattens out rapidly due to a small spoon-shaped synclinal fold and the outcrop of the bed bends suddenly to the

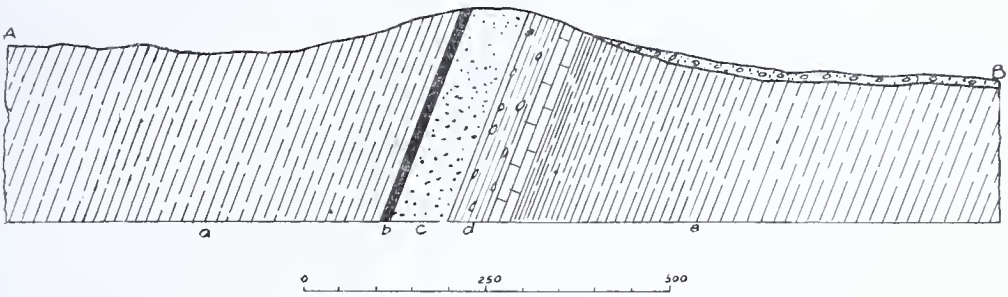


Figure 6- Section along line A-B, Plate XV. a, Marcellus shale b, "paint beds", c Oriskany sandstone, d, Helderberg limestone; e, shales.

south. It was at this point that the first work was done, a drift being run in on the bed which dipped about 24° N. and in certain places even less. The dip soon becomes steep again and along the south side of the southerly Oriskany ridge the dip varies from 65° N. to 84° N. Just west of the Lehigh River this ore body disappears, due

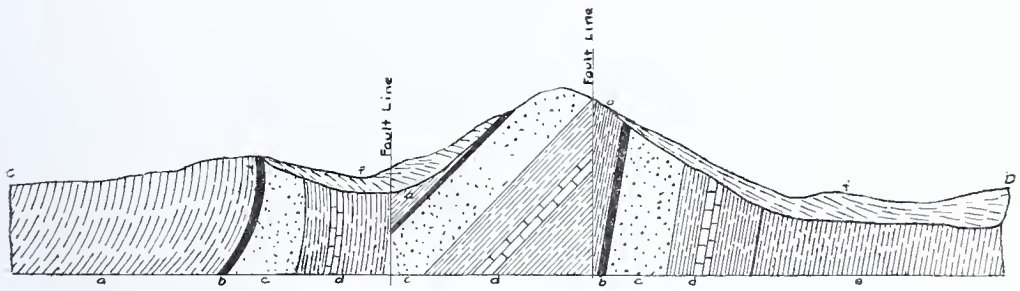


Figure 7- Section along line C-D, Plate XV. a, Marcellus shale, b, paint beds, c, Oriskany sandstone; d, Helderberg limestone, e, Salina shale; f, Hillside wash.

to a strike fault that follows closely the southerly base of the steep part of the south ridge as shown on the map.

On the north side of the south ridge the ore bed is undoubtedly present but no work has yet been done there.

Another strike fault occurs in the valley between the two Oriskany ridges and the ore again appears on the north side of the ridge running near Bowmanstown. The ore has been worked at a few places a short distance to the southeast of the town and no doubt extends east along the north slope of the ridge to the place where it meets the first fault mentioned. No data are available concerning the dip of the ore bed but from the dip of the Oriskany which here

forms a vertical wall extending for over a mile the ore stratum probably has a dip of more than 80° to the north and may possibly be overturned to the south in places.

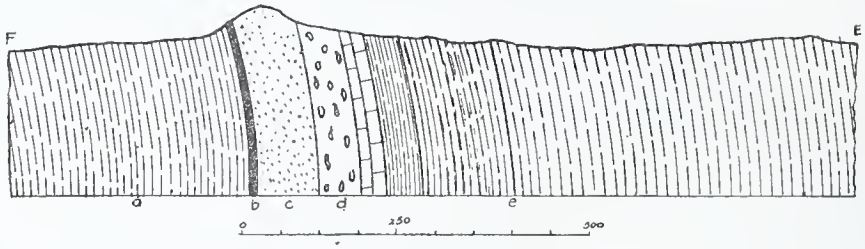


Figure 8- Section along line E-F, Plate XV. a, Marcellus shale; b, paint beds, c, Oriskany sandstone; d, Helderberg limestone; e, shales

This north line of outcrop extends in a continuous line across the Lehigh river westward to Germans. From Bowmanstown to the vicinity of Pennsville the dip seems to be nearly vertical, sometimes overturned slightly. About midway between Pennsville and Germans the dip again becomes slight, due to a small spoon-shaped fold similar to the one near Hazard. In this fold which causes the outcrop to bend to the south the dips vary from 12° to 18°. Farther west and just east of the road leading south from Germans the dip is said to have been 58° N.

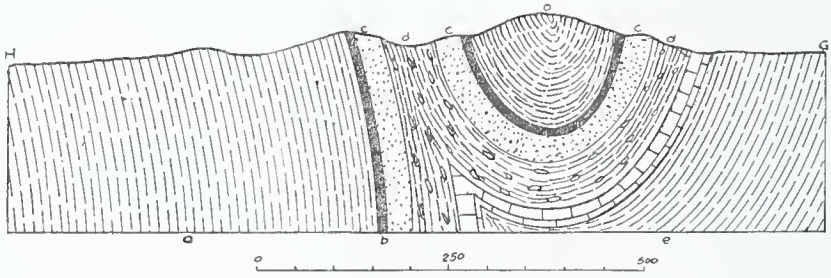


Figure 8- Section along line G-H, Plate XV a, Marcellus shale; b, "paint beds"; c, Oriskany sandstone; d, Helderberg limestone; e, shales.

At Germans a cross fault has thrown the outcrop a short distance as shown on the map. Some shafts have been sunk west of this fault line but no data concerning them are available.

Origin of the Paint Ore.

The origin of the paint ore has not been definitely determined. Two theories are proposed to account for it. According to one view the ore was originally deposited in the ocean in essentially the same form in which we find it today; that is the iron has been present in the bed ever since its deposition. The other view explains the presence of the iron as due to secondary changes subsequent to the deposition of the strata.

Original deposition theory.—The almost complete absence of iron in the Oriskany sandstones underlying the paint ore of this region suggests its deposition during a period when the streams were carrying little iron in solution, but were loaded with quartz sands carried in suspension. The size of the grains, many of which are more than an inch in diameter, indicate swift currents which imply rapid degradation of the land. If iron compounds were produced in the disintegration of the rock yielding the quartz grains and pebbles it did not have sufficient time to be oxidized and the quartz fragments are free from iron oxide which would tend to coat the grains.

Following the deposition of the Oriskany conditions changed and the only materials reaching this locality were extremely fine sediments. These may be accounted for as due to the greater distance of the shore or possibly the lowering of the land surface so that the streams had their velocity checked to such an extent that they were able to carry only the finest debris. Under the latter conditions the iron of the rock furnishing the materials would have sufficient time to oxidize and the fine mud particles were probably colored red to brown by the iron oxide present. Calcareous matter was being deposited at the same time either from solution or by the accumulation of animal remains. That animals lived there in abundance is proved by the preservation of their fossil remains in the ore. The resulting deposit was a bed of muddy calcareous rock rich in iron oxide. Again, the iron may have been carried in solution in the form of iron carbonate and deposited on the bottom in the form of bog iron ore due to the oxidation resulting from the elimination of gases from decaying organic matter. It is possible that the iron brought in solution at once replaced part of the calcium of the calcium carbonate and the deposit as first formed was a rock containing mud, calcium carbonate, and iron carbonate. It seems more probable, however, that the iron was not changed to the ferrous condition until the overlying Marcellus-Hamilton carbonaceous shales were laid down on top of the cement rock and ore bed. The siderite deposits of the Coal Measures are supposed to have been formed in a similar manner and certainly the basal beds of the Marcellus-Hamilton contain sufficient carbon to produce such an effect. As stated on a preceding page the basal beds are so rich in carbonaceous material that attempts have been made to find coal in them.

The pyrite in the ore is also believed to be due to the presence of the organic matter in the Marcellus-Hamilton shales. Van Hise* states "that artesian waters held in sediments containing organic material are frequently marked by the persence of hydro-sulphuric

*A Treatise on Metamorphism, p. 1112.

acid." Water carrying sulphuric acid would tend to convert some of the iron of the lower beds into iron sulphate which would subsequently be readily reduced to iron sulphide by the carbo-hydrogen gases given off from the decaying vegetation of the carbonaceous shales.

Replacement Theory.—The other theory is that the ore bed represents merely a portion of the cement bed in which iron carried by descending waters from the overlying strata has replaced a portion of the calcium in the original calcareous deposit. White* describes deposits of brown hematite iron ore in these basal black slates at Kunkletown and Bonser's. At the former place it was once burned and manufactured into mineral paint. The brown coating on these weathered shales also shows the amount of iron which they contain. It is therefore possible for sufficient iron to have been removed from the overlying rocks to have produced all the iron of the paint ore. This replacement was by metasomatism by which the iron was substituted for the calcium without destroying the fossils or the structure of the rock. The pyrite is believed to have been formed in the same manner as described in connection with the discussion of the preceding theory. The bed of clay underlying the ore body would effectively stop the downward percolation of the iron-bearing waters and so favor replacement of the immediate overlying beds. Deposition and replacement always take place more readily from stagnant waters than from freely moving streams.

The practical importance of determining the origin of the ore is considerable for on it depends the extent of the ore body. According to the original deposition theory the ore body should show no diminution in thickness or richness with depth as it has no connection with existing conditions. On the other hand if the replacement theory is correct the ore should be found to decrease in value with depth as metasomatic replacement from descending waters does not take place much below the permanent level of ground waters. Data obtained from many sources is conflicting in regard to the change of the ore with increased depth. Some persons employed in the district maintain that the ore grows leaner as the distance below the water level is reached while others maintain the reverse. The latter say that the richest ore occurs below water level as there it exists in its original form while that at higher levels has lost some of its iron content due to leaching. With such conflicting data the true explanation of the formation of the ore must be left to a time when more reliable information can be obtained.

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*Second Pa. Geol. Surv., Report G 6, p. 114.

Extent of Work in the District.

In the southern band of ore there are very few gaps between the Lehigh River and Little Gap where the bed has not been worked. There has been so much work done along the outcrop that it is possible to trace the bed almost the entire distance by the line of sink holes and abandoned shafts. From Bowmanstown to Germans along the northern line of outcrop conditions are similar. However, the ore has not been exhausted by any means as practically all the workings have been shallow and considerable quantities of ore above the level of the water in Lehigh River still remain. The amount and extent of the workings cannot be determined now as most of the shafts and tunnels have long been abandoned and have caved to such an extent that it is impossible to enter them to take observations.

Mines in Present Operation.

At the present time three companies only are operating in the district. These are the Prince Manufacturing Company, the Prince Metallic Paint Company, and the William G. Freyman Company.

The Prince Manufacturing Company is operating two tunnels and one shaft a short distance northeast of Hazard, while another shaft is now being constructed. The tunnels and shaft cut the ore body at different elevations and the workings of the two tunnels and shaft are all connected. The Kline tunnel is the lower and oldest one. It starts in the hill-side wash, which here is thick, and extends 1,400 feet in a north-south direction to the ore body. Drifts are driven on the ore bed both east and west and the ore is stoped out by the overhead method.

The next tunnel lies farther up the hill and to the east and is considerably shorter, while the shaft lies to the northeast of the second tunnel and is sunk near the outcrop. The ore has been stoped for such a distance from the Kline tunnel that it is the intention of the company to abandon it soon except for purposes of drainage for which it is very effective, due to its connection with the upper workings.

The Prince Metallic Paint Company is operating a shaft and tunnel about $1\frac{3}{4}$ miles east of Millport. The tunnel runs into the base of the hill starting at the level of the road and cuts the ore body in about the center of the hill. The ore body, which has a thickness of $2\frac{1}{2}$ feet, in places, has been worked for a distance of over 2,000 feet along the strike. Owing to the height of the stopes a shaft was later sunk on the top of the hill and at present the principal work is done through this shaft. Several small shafts for ventilation have been opened to the surface from the stopes.

The William G. Freyman Company is now operating at Little Gap in an old mine of the Prince Manufacturing Company. The work is being done through a tunnel that starts on the ore bed near the level of the creek and runs almost due west into the hill for a distance of 2,000 feet. The work thus far done in this mine is of the nature of development work as no ore has been shipped, although there is a considerable supply on hand. The ore body has a dip of 80° N.

Methods of Mining.

From the descriptions of the mines already given the general methods of mining may be inferred.

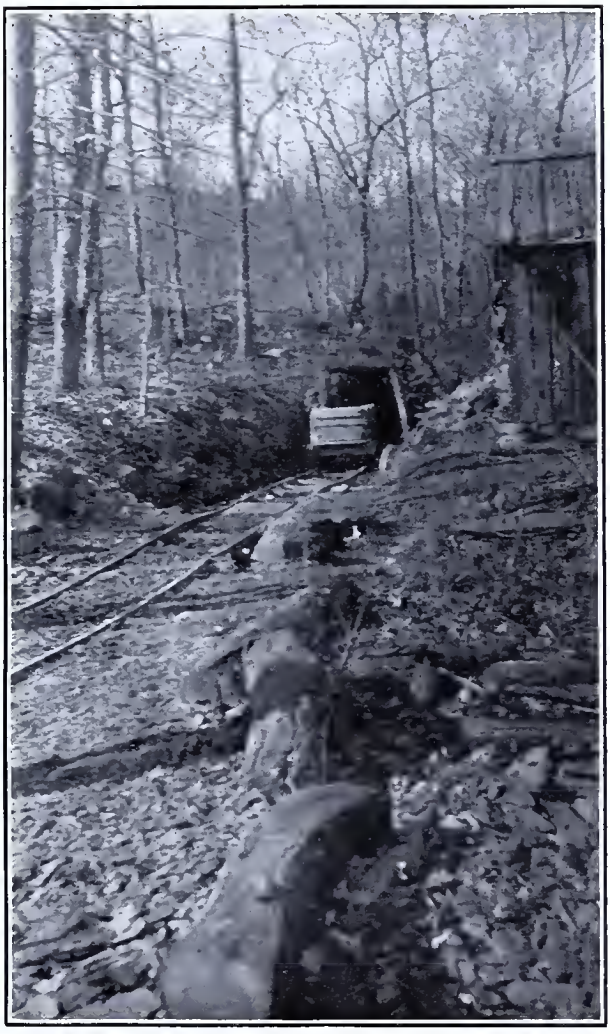
At present the deposits are worked by both tunnels and shafts and in the past in the two places previously described where the dip of the bed was slight the ore was mined through slopes driven on the bed.

Owing to the position of the ore on the slopes of the steep Oriskany ridges the tunnels have almost all been driven into the hill at right angles to the strike of the bed. The exceptions to this are at a point one-half mile south of Bowmanstown where the Lehigh River cuts the ridge and at Little Gap where Princess Creek has cut a gap through which it flows to meet the Aquashicola Creek. At the former place the Prince Manufacturing Company at one time drove a tunnel on the bed eastward about 3,900 feet. At the latter locality the William G. Freyman Company is now at work on a tunnel starting on the ore body and following it westward 2,000 feet.

Other tunnels are driven in the side of the hill until they reach the ore body and then drifts are run in either direction.

"The Kline tunnel of the Prince Manufacturing Company at Hazard may be taken as a typical example of the tunnels of this region. This tunnel starts in the river wash, which here covers the side of the hill, and extends 1,400 feet in a north-south direction to the ore bed. From the end of the tunnel drifts are driven along the strike of the bed, which is east and west, and the ore is stoped out by the overhead method, with filling. Where the tunnel goes through a great thickness of soft shale and clay, close timbering and lagging is necessary. The tunnel is 6 feet high and about as wide. The sets consist of two posts and a cap of 8-inch timber and are placed 3 to 6 feet apart. They are lagged with rough poles 15 feet long. The track has a gage of $2\frac{1}{2}$ feet. No timbering is necessary in passing through the Helderberg limestone or the Oriskany sandstone.

"The mines of the Prince Metallic Paint Company east of Millport probably show to best advantage the mining methods in use, and a detailed description of one of these mines follows:



XVIII.—Tunnel Opening of Prince Manufacturing Co., Hazard.

Plate XIX.—Shaft House of Prince Manufacturing Co., Hazard.

Plate XX.—Kilns of Prince Manufacturing Co., Bowmanstown.

"The ore bed here outcrops well back in the Oriskany hill and dips steeply from 60° to 70° due north. It has been worked for 2,000 feet along the strike, and a timbered air hole marks the present western limit of the workings. One thousand feet east of this the bed was first encountered by a tunnel driven from the hillside 999 feet due north. Six hundred feet east of the point where the tunnel strikes the bed is the bottom of the shaft, and from this point the workings continue 400 feet farther east. This tunnel is similar to the one described above. A shaft was put down in the hanging wall and struck the bed at a depth of 159 feet, the same level as that at which the tunnel enters it. The shaft is 5 feet square and is timbered with 6-inch cribbing, on the inside of which are nailed 1-inch boards forming a complete lining.

"The drifts along the strike are 7 feet high, 5½ feet wide at the bottom and 5 feet at the top. They are driven along the ore, which is here 2 feet thick, and are timbered their entire length. Only one post is used in the sets, as the cement rock hanging wall is sufficiently firm to permit supporting one end of the cap in a hitch cut in it. Nine-inch timber is used. The sets are placed 3 feet apart and are closely lagged.

"A pillar is left to protect the shaft, and beyond this the stoping commences. The drift is driven 30 to 40 feet at a time, after which a section of this length is stoped up to the surface, or to the overburden of earth and clay. Overhead stoping with filling is the method used. The stope is kept inclined in advancing, so that the top corner farthest from the shaft is kept about 20 feet ahead of the face of the drift. The ore can thus be rolled down from the working face to the drift. Six-inch props are placed at intervals to support the roof while the ore is being removed. The stopes are 4 to 6 feet wide, 2 feet being ore and the rest clay and cement rock. The ore is carefully sorted out and rolled down. The clay and cement rock are used as filling. At intervals air holes are driven from the top of the stopes to the surface. The air is then carried from them to the working places by a small monkey gangway, which runs along the top of worked-out and filled-in stopes. This also is timbered and lagged. As the workings advance, new air holes are driven and the old ones are abandoned.

"The ore is blasted down with dynamite, the holes being drilled by hand. After being sorted and rolled down to the drift it is loaded into boxes holding about half a ton. The boxes have rings at the corners, and four chains suspended from the hoisting rope are hooked in these rings. The hoisting is done by a horse hoist. The ore, after hoisting, is stored in sheds ready for the mill.

"This mine is rather wet, but the natural drainage through the tunnel disposes of all the water. At present one shift of four men is engaged in stoping and the output is 10 tons a day."*

At present no mines are being worked by slopes although two were worked in this manner formerly in the two places in the district where the dip of the ore bed is slight, as described on a previous page.

Preparation of the Product for Market.

The treatment of the ore is simple as only two processes are involved, calcining and grinding to a fine powder when it is ready to be mixed with oil to form paint.

Although there have been many kilns and mills in the district at various times there are only three now standing and only two in operation. The active ones are those of the Prince Manufacturing Company at Bowmanstown and the Prince Metallic Paint Company at Lehigh Gap. The mill owned by William G. Freyman at Little Gap is in good condition but has scarcely been operated because of lack of ore. The mills and kilns are all essentially alike.

The ore is hauled in carts from the mines to the mills where it is stored in sheds until used. As it comes from the mine it is mainly in lumps 10 to 14 inches in diameter and it is necessary to break it into smaller pieces before burning in order that the calcination may extend through the entire mass. This is done by means of sledges and the maximum size of the fragments is about 6 inches in diameter. It is then trammed to the kilns which are generally situated on the side of a hill with the ore bins at a higher level so that the ore can be carried over a trestle to the charging door at the top of the kiln without being elevated. The kilns were formerly built of stone but now the best are of brick construction, with sheet-steel sheathing 25 feet high and 10 feet in diameter. The fire boxes are built on either side of the kiln and increase the width at the base to 18 feet. The fuel used is wood and the ore is heated to a cherry red. The ore remains in the kiln about 24 hours, 10 tons being withdrawn every 12 hours and an equal amount of raw ore added at the top. The object of calcination is the elimination of the sulphur of the pyrite and the conversion of the iron into the oxide. In the raw condition the iron is in part combined with carbon dioxide to form siderite and in part united with sulphur as pyrite. In this change the ore is changed from its blue color to a dark reddish brown and is also rendered much less tenaceous. The moisture is also driven off during the burning. The loss in the process is about 20 to 25 per cent.

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*Agthe and Dynan, Paint Ore Deposits near Lehigh Gap, Pennsylvania. U. S. Geol. Survey, Bulletin No. 430, pp. 450-452, 1910.

Plate XXI.—Grinding House of Prince Manufacturing Co., Bowmanstown.

Plate XXII.—Ore Sheds of Prince Metallic Paint Co., Millport.

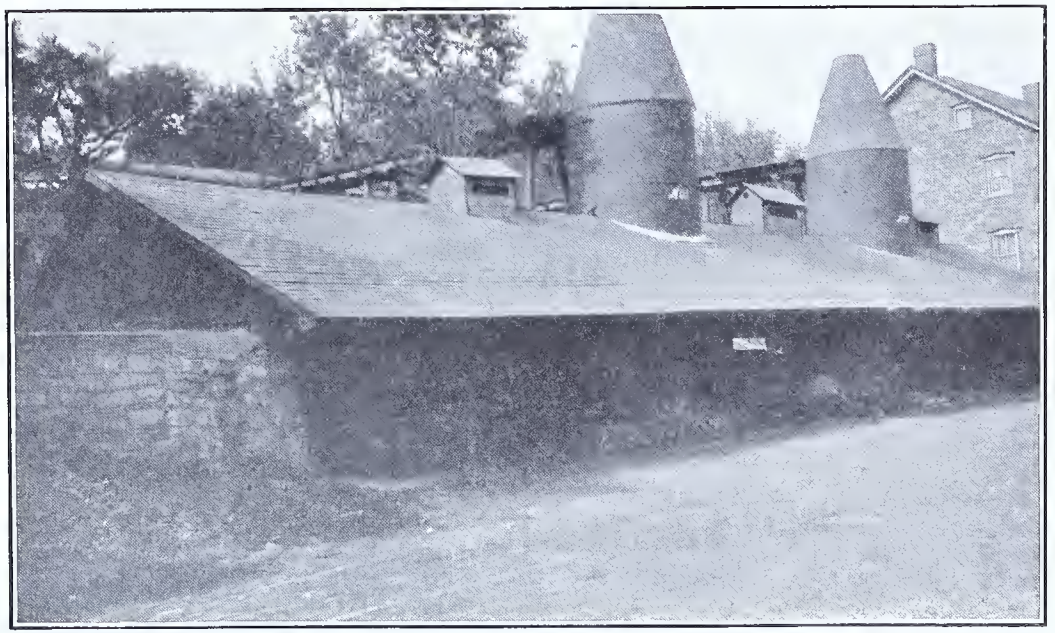

Plate XXIII.—Kilns of Prince Metallic Paint Co., Lehigh Gap.

Plate XXIV.—Grinding Mill of Prince Metallic Paint Co., Lehigh Gap.

The final stage is the grinding which is done in mills situated near the kilns. At the Prince Metallic Paint Company's mill at Lehigh Gap the calcined ore is first fed to a gyratory crusher where it is ground to buckwheat size. It is then conveyed to bins on the top floor and fed to finer grinding mills on the floor below. These mills consist of three 36-inch horizontal buhr and three vertical mills. The product is shipped mainly in barrels containing 300 or 500 pounds. All the mills now in operation in the district are run by water power.

Composition of the Finished Product.

As has been stated above the chemical composition of the ore is materially changed during calcination. The Prince Metallic Paint Company gives the following analysis of their product when ready for market:

Fe_2O_3,	41.0 —47.0
SiO_2,	32.0 —37.0
Al_2O_3,	9.0 —11.0
CaO,	0.1 — 3.0
MgO,	1.7 — 3.5
MnO_2,	0.35— 1.8
P_2O_5,	0.14—0.17
S,	0.5 — 1.0
CO_2,	1.5 — 2.5
H_2O,	0.6 — 0.9

The Prince Manufacturing Company has furnished the writer with the following analysis of their finished product:

SiO_2,	38.65
Fe_2O_3,	43.70
Al_2O_3,	5.79
MnO_2,	1.85
CaO,	1.80
MgO,	2.04
Moisture at 105°,	0.30
Ignition loss above 105°,	2.54
Undetermined,	3.33
	100.00

Properties and Uses.

The manufacturers claim that the paint as marketed has some of the properties of a Portland cement as the original rock is a variety of cement rock. It sets as does cement and therefore requires no drier. Free silica which is objectionable in a paint is absent. The manufacturers claim that seven pounds of paint mixed with one pound of boiled linseed oil will cover 500 square feet. The claims for its great durability under the most severe conditions seem to be well substantiated.

The greater part of the paint from this region is used for painting structural steel, bridges, tanks, ships, cars, and tin roofs. More is used in painting freight cars than for any one other purpose. It also serves as a filling in oil cloth and linoleum.

The current price varies from $12 to $14 a ton.

Production and Statistics.

The present annual output of the district is about 5,000 tons. The number of men employed in the mines and mills is about 50.

The total output since the beginning of operations in 1856 is roughly 100,000 tons.

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CHAPTER VI.

BLACK SHALES UTILIZED FOR PIGMENTS.

Black shales, ground and sold under the name of mineral black, are extensively used in the manufacture of paint in many places. "Mineral black is a pigment made by grinding a black form of slate. It contains a comparatively low percentage of carbon and consequently has low tinting value. It finds use as an inert pigment in compounded paints, especially for machine fillers. The pigment has a flocculent appearance, the particles showing a strong tendency to mass."* Black shales are found widely distributed throughout Pennsylvania, occurring in every Paleozoic period and in a great many of the formations. In many places the material has been dug for paint purposes while in some of the slate regions the refuse about the quarries has been shipped to paint factories. A limited use has been made of the culm heaps about the anthracite coal mines and the disintegrated surface coal near the outcrop. There is a tendency for most of the black shale material to settle out of the oil, as mentioned in the quotation above, but this is not a serious objection. The durability of the paint in which the black shales have been used is vouched for by many persons who have used it. While some is used in making paint for buildings most of it is utilized in the manufacture of a black filler for iron work. The descriptions of individual properties which follow probably include all the most important operations of the present time but, no doubt, many localities where black shales were formerly quarried as pigments are omitted. Places where black shales suitable for paint occur are likewise omitted on account of the great number of black shale strata in the State and the additional fact that it would be necessary to make paint tests of the various shales to determine their adaptability. Certain it is, however, that the supply of black shales for pigments is infinitely greater than the limited demand.

Plant of Keystone Paint and Filler Company, Muncy

The largest producer of black shale pigments in the State is the Keystone Paint and Filler Company of Muncy, Lycoming County. Their mill is located close to the station of the Philadelphia and Reading Railroad at Muncy while the quarries furnishing the shales

*The Properties and Structure of Certain Paint Pigments. Bull. No. 29, Scientific Section, Paint Mfgrs. Assoc. of U. S., p. 35.

are situated south of the town close to the bank of the Susquehanna River. This company has been in operation for more than 25 years and the Keystone Black Filler made by them is widely known by paint manufacturers.

At the present time the company is operating two quarries. The one from which they have obtained their shales for many years is located along the left bank of the Susquehanna River one mile south of Muncy Station, just below the Philadelphia and Reading Railroad bridge. The shale forms a part of the Lower Helderburg formation which is composed, in the main, of limestones but in certain sections includes considerable shale. At the quarry the shale, which is of a dull dead black color, is interbedded with black argillaceous limestones, which in certain places are in the form of lenses varying from a few inches to a few feet in thickness and from 1 to 20 feet in length. The shale also contains enough $CaCO_3$ in most of the strata to produce a feeble effervescence with dilute acid. The layers of rock that contain much $CaCO_3$ are cast aside. The black color of the shale is caused by a considerable percentage of organic matter. Pyrite in the form of tiny crystals and in larger nodules occurs in the shale and these nodules are numerous enough in certain places to render the rock valueless. At the quarry the strata dip 26° in the direction of S. 8° E. In the section of shales exposed along the river bank there are certain layers in which pyrite nodules ranging in size from 1 to 4 inches are very common. Thin veins of calcite and pyrite are also occasionally encountered.

No analyses of the rock as taken from the quarry are available but the following analysis made by Harrison Bros. and Co. of the finished product (Keystone Black Filler) probably represents the average composition of the rock better than a single analysis of a picked sample:

SiO_2,	57.53
Al_2O_3,	16.72
Fe_2O_3,	4.52
FeS_2,	3.76
$CaCO_3$,	4.12
MgO,	1.38
Na_2O,	1.06
K_2O,	2.12
Water,	3.19
Organic matter (carbon),	5.60
	100.00

The rock is hauled by wagon to the mill at Muncy where it is prepared for shipment. It first passes through a jaw crusher, thence to a Sprout-Waldron mill, and from that to a Raymond pulverizer where the finer particles are separated by air from the coarser ones. From the collecting bin the fine powder is packed in kegs or barrels of 100 to 400 pounds capacity. The bulk of the material produced is shipped in the dry form but some is made into paint directly as the company also is engaged in the manufacture of mixed paints. Three grades of Keystone Black Filler are produced depending upon the fineness of grain.

It is recommended by the company "as a filler or rough stuff for automobiles, carriages, buggies, passenger cars, safes and all similar work on which a filler is used to make a surface, including machinery, machine tools, farming implements and all kinds of iron work."

Another product made by the same company from shales of lighter color is sold under the trade name of "alumino-silex."

Plant of Penn Keystone Company, Williamsport.

The Penn Keystone Company, with offices at Williamsport, is operating a mill about one mile S. W. of Antes Fort P. O. (Jersey Shore Station on the Pennsylvania Railroad) in the gap where a stream cuts through Bald Eagle Mountain. The company is engaged in the manufacture of a black filler which is similar to that produced by the Keystone Paint and Filler Company of Muncy. The building now used as a mill was originally a woolen mill while the old paint mill at Antes Fort formerly used has now been abandoned.

The company obtains the rock from the Nippenose Valley near Rauchtown. Until recently it operated a quarry on the farm of J. S. Group about one-fourth mile from Rauchtown, but at present is working a quarry on the farm of R. H. Overdorf about one mile W. of Rauchtown. The material in the two quarries is similar except there is perhaps a larger amount of calcareous matter present in the former locality.

The rock is a black carbonaceous argillaceous limestone occurring in the uppermost portion of the Trenton limestones. Fossils are rare in the material best suited for the production of the black filler but are abundant in the interbedded layers of purer limestones, particularly at the quarry close to Rauchtown. These fossils are of Trenton age.

The amount of carbonaceous matter is large and in the weathered portions of the rock where the rock is decomposed through the removal of most of the $CaCO_3$ the black matter will rub off readily and resembles a brown lignite in appearance. Pyrite is present in the rock in tiny crystals, in nodules, and in small veins.

An analysis of the finished product furnished by the General Manager, Mr. C. T. A. Mallalieu, is as follows:

Silica,	59.24
Alumina,	17.10
Iron oxide,	7.26
Potassium oxide,	3.34
Calcium oxide,	1.70
Sodium oxide,	.96
Magnesium oxide,	.22
Manganese,	Trace
Volatile matter and combined water,	9.86
	99.68

In both quarries the rock comes to the surface so that no strpiping is required.

The rock is hauled from the quarry to the mill by wagon where it is allowed to dry by air in a shed after which it is crushed, ground, and bolted. All the material passes through 4 or 5 bolts, the last a wire screen of 180-mesh. The mill is operated by water power. The final product is hauled to the Jersey Shore (Pennsylvania Railroad) Station where it is shipped. The company does not manufacture any of the product into mixed paints.

At the same mill some rock obtained from the Nippenose Valley is also ground and sold as rotten rock for polishing purposes. The locality where the material is obtained was not visited but the rock is evidently an impure Trenton limestone with much of the lime removed by solution.

Black Filler Deposits near Allenwood, Union County.

Along the left bank of the Susquehanna River just below Fritz Station on the Philadelphia and Reading Railroad on the farm of Mrs. John Myers of Allenwood, black shale belonging to the Hamilton formation has been dug for paint purposes. The quarry is located so close to the river that it is covered with water when the river rises a few feet above normal. The rock has not been extensively worked, the total output being two cars during the summer of 1909 and a like amount in 1910. It was shipped to the mill of J. Wilbur Company in Philadelphia for grinding.

The rock is black in color and consists of argillaceous and carbonaceous matter with a small amount of $CaCo_3$ and pyrite. It breaks as argillaceous limestones do but the percentage of $CaCO_3$ is so low that the rock can scarcely be termed a limestone. One thin layer of limestone containing fosils was observed interstratified with the shale.

A short distance to the south of the above deposit and farther from the river is a place where black shale was formerly worked. Nothing of the former workings can now be seen. The following description by E. V. d'Invilliers published in his geological report* on this county is therefore quoted:

"The Tate Paint Mine has been opened appartently in the Marcellus division of these rocks, just west of the P. & R. R. R., and about 1½ miles north of Allenwood. It is presumably the Marcellus ore bed which had been developed here, although unfortunately the opening was so badly fallen in as to prevent any personal examination. Mr. Tate reports that the main drift had been driven 75 yards west into the hill, with gangways north and south in a flat bed of carbonate ore. The bed is capped with black slate, with thin but regular layers, under which there is 2 feet of black carbonate ore furnishing only 10 per cent. of metallic iron. A stratum of 6 feet of hematite ore underlies the carbonate, and a half-inch of yellow ochre on the bottom. Several carloads of the black carbonate ore have been shipped to the Allenwood Paint Mill, where it is dried and ground and is said to make an excellent black paint or polish for iron and wood structures.

"The mining of this material is necessarily very cheap as it is said to yield to the pick, although the gangways require a large amount of timbering to preserve the roof of the mine.

"The 6-inch band of hematite ore, after being roasted, has been treated in the same manner and makes a brown paint somewhat siliceous, which does not command so high a price.

"No work has been done at this opening for nearly three years, so that the facts are recorded simply as Mr. Tate has kindly offered them. No limestone is reported to occur at or near the opening and the raw material, as mined, is intensely black, without grit and sooty. It stains the fingers as lamp-soot would do, and when used as a pigment it is said to be very durable and will not fade. It has been shipped to Williamsport, Reading, Harrisburg, and elsewhere through Central Pennsylvania."

Black Slates of Lehigh and Northampton Counties.

The Martinsburg formation in Lehigh and Northampton counties contains many layers of good slate that have long been worked for roofing slate, blackboards, billiard table tops, etc. In every slate quarry the greater part of the rock removed is waste and it accumulates in enormous quantities about some of the large quarries. Considerable of this refuse slate has been shipped to paint mills where it has been ground and used in mixed paints. From the Old Bangor

*Sec. Geol. Surv. of Pa., F 3, pp. 87-88. 1891.

quarry at Bangor considerable has been shipped to local plants and some to Chicago. The cost is very little more than the freight charges as the slate companies are glad to have it removed. Slate refuse from the quarries at Bangor, Slatington, and near Weaversville has been so used.

The following analysis of the Old Bangor slate furnished by Mr. J. S. Moyer, is typical:

Silica (SiO_2),	56.97
Oxides of iron and alumina (Fe_2O_3 and Al_2O_3),	26.05
Carbonic acid and organic matter,	7.14
Calcium oxide (CaO),	4.38
Magnesia oxide (MgO),	2.69
Sulphur (S),	0.46
Sodium and Potassium oxides (Na_2O and K_2O),	2.31
Manganese,	Trace
	100.00

H. D. Rogers in "Geology of Pennsylvania" (Vol. I, p. 249) describes the use of certain materials from what is now known as the Nazareth formation, "which is on the line dividing the slate from the limestone formation, a material is procured which answers well the ordinary purposes of *black paint*. This appears to be simply a more than usually carbonaceous black, and soft variety of the Matinal black slate, occurring near the base of the formation a little above its contact with the limestone. It occurs also further east on the Bushkill, and has been found likewise on the Union Canal, in a corresponding situation in the stratum. It requires to be ground in a drug-mill, and levigated in troughs, by passing over it a stream of water. Thus prepared, it constitutes, when mixed with oil, a very excellent pigment for the exterior of houses, fences, and other structures exposed to the weather."

Black Shales and Coal of the Coal Regions.

The black shales of the Coal Measures have also been used in the manufacture of paint to a limited extent. The culm, which is a mixture of coal dust and shale, has also been used, while a few years ago black paint was made from the disintegrated outcroppings of coal seams in the Schuylkill region near Pottsville.

CHAPTER VII.

YELLOW SHALES UTILIZED FOR PIGMENTS.

Yellow shales occur in many places throughout the State and at several geological horizons, but particularly in the Martinsburg and Mauch Chunk formations. In a number of places these shales have been utilized in the manufacture of paint and when ground fine and mixed with oil are very serviceable. Their principal use, however, is in the manufacture of oil cloth and linoleum. They are considerably lighter in color than the ochers and contain a much lower percentage of hydrous iron oxide, seldom more than 5 per cent. Yellow shales that are worked for paint are usually called ochers but such usage is plainly not justified.

Plant of Luzerne Ocher Manufacturing Company, Moosehead, Luzerne County.

In the vicinity of Moosehead Station on the Lehigh Valley Railroad yellow shales have been worked continuously for about 50 years. The present company is the Luzerne Ocher Manufacturing Company with offices in White Haven. The first operations were close to the railroad tracks where the shales outcrop in a shallow cut and in a ravine nearby, but the present workings are located about 1½ miles east of Moosehead and about 5 miles north of White Haven. At the former site the shales were first quarried at the outcrop but as the overburden increased tunnels were run in on the bed. The roof, however, proved to be so poor that tunnels were abandoned and the plant moved to its present location where the shales can be worked by open cut, with a minimum amount of stripping. The region is one of the most thinly inhabited sections of the State as the soil is not suited for agriculture; there are no mineral deposits of importance other than the one described in this article; and the frequent forest fires that sweep over the region have largely destroyed the best timber. The forests have all been cut at one time and now the land is covered with a growth of fern brakes, shrubs, and occasional trees that have survived the forest fires.

The rocks of the region belong to the Pocono sandstone and the Mauch Chunk shales which constitute the Mississippian Series of the Carboniferous system. These two are of great thickness and outcrop over extensive areas; the former consisting of resistant gray sandstones and conglomerates with some interbedded shales varies in thickness from 800 to 1,300 feet while the latter consists primarily of shales yellow, red, and greenish-gray in color with some inter-

bedded sandstones and conglomerates with a total thickness of about 1,000 feet. The strata have been thrown into folds but the anticlines and synclines are low and the dips consequently of small degree.

The paint shales occur near the base of the Mauch Chunk formation and have been traced by outcrops from near Tunnel Station on the Central of New Jersey Railroad eastward for a distance of about three miles. The best exposed section of this portion of the formation is in the railroad cut at Moosehead where the paint shales were first worked. The following section at that point is taken from a report by Arthur Winslow on the Lehigh River Cross Section.*

	Feet.
Conglomerate, gray, siliceous, medium,	20
Sandstone, gray,	4
Conglomerate, gray,	6
Sandstone, gray,	3
Conglomerate, gray,	3
Sandstone, gray,	7
Sandstone, gray, with quartz and red shale pebbles,	15
Conglomerate, slate pebbles, large red shale fragments,	5
Sandstone, hard gray,	5
Shale, red, with red ochre,	28
Shales, yellowish green,	10
Ochre, yellow, Luzerne Ochre Mfg. Co. Mines,	16
Ochre, white, Luzerne Ochre Mfg. Co. Mines,	2
Total,	124

The section exposed in the quarry now being worked consists of 15 feet of buff yellow shales (the paint shales) overlain by 12 feet of red shale.

The paint shale is light yellow in color with the shaly laminations less well developed than in most shales. An analysis furnished by S. S. Staples, President of the operating company, is as follows:

Silica (SiO_2),	64.24
Alumina (Al_2O_3),	22.40
Iron oxide (Fe_2O_3 and FeO),	4.80
Combined water,	5.70
Undetermined properties,	2.86
	100.00

*Sec. Geol. Surv. of Pa., An. Rep. for 1886. Pt. IV, p. 1345, 1887.

Winslow in article cited, (p. 1346) gives an analysis of the paint shales formerly worked at Moosehead. It was made by Hugh Hamilton and is as follows:

Silica (SiO_2) largely free and destructive to the mill stone,	57.36
Alumina (Al_2O_3),	27.44
Protoxide of iron (FeO),	1.62
Peroxide of iron (Fe_2O_3),	2.94
Sulphate of lime ($CaSO_4$),	1.93
Sulphate of magnesia ($MgSO_4$),	0.66
Organic matter,	4.50
Water,	0.85
	97.30

The mining is done by open cut, the overlying red shale being first blasted down and thrown in that part of the quarry where the paint shales have been removed. Dynamite is used to enlarge the drill holes and then black powder to shatter and bring down the material. The shale is then broken into smaller pieces and trammed to the mill nearby where it passes through two crushers and is reduced to the size of three-eighth inch. It is then run through a Cummer dryer. After cooling it is ground in buhr-stone mills and bolted through fine silk screens of 156-mesh. There are twelve sets of screens arranged in a parallel series and slightly inclined in order to cause the material to move along through them as they are revolved. The coarses particles that pass out at the lower end are taken back to the mill where they are reground. The screens have a capacity of about 20 tons per day. From the screens the product goes to the stock house or to a bin where it passes through tubes to bags. A spur of the Lehigh Valley Railroad runs to the plant facilitating shipment.

The finished product, called ocher, is used in the manufacture of oil cloth and linoleum and forms a good base for printing. The output is about 2,500 tons per year and the price about $3.50 per ton f. o. b. The supply of the material is practically unlimited as the company owns a tract of 3,000 acres and it is claimed that the yellow paint shales extend under the greater portion.

Yellow Shales near Rockport and Penn Haven Junction, Carbon County.

For several years Mr. M. L. Smith, recently deceased, operated paint mills at Slatington, Lehigh Gap, and Hudsondale using yellow shales of the Mauch Chunk formation obtained near the tunnel of the Central of New Jersey Railroad at Rockport, and near Penn Haven Junction. Later these localities were abandoned and he gave his entire attention to grinding red shales from the same formation obtained near Hudsondale which are described in another section of this report.

Yellow Shale near Shoemakersville, Berks County.

Yellow ocherous shale was dug about two years ago along the Pennsylvania Railroad tracks opposite Perry Station of the Lehigh Valley Railroad on the farm of J. K. Weidman of Shoemakersville. The shale is light yellow or buff in color, and contains little grit. It forms a part of the Martinsburg (Hudson River) formation which consists mainly of dark-colored shales especially in Northampton and Lehigh counties but passing westward interbedded red and yellow shales become more common. Where worked the shale dips to the southeast at an angle of about 25 degrees.

Two carloads only were dug at this locality, both of which were obtained by the J. Wilbur Company of Providence, R. I., and Philadelphia. It was found to be of conisderable value as the base for oil cloth and linoleum, but no more was dug because of the inability of the owner of the land and the operator to agree on the matter of royalty. The supply is undoubtedly very large and the deposit is so located that it can be easily and economically worked.

Similar material occurs at many places in this formation, although, so far as known, little use has been made of it. The percentage of iron is low, yet for many purposes it is very serviceable. One mile north of Myerstown a deposit of yellow shale is said to outcrop that has the appearance of being suitable for the manufacture of a coloring base for oilcloth although none has yet been used in that way.

Yellow Shale of North Mountain, Wyoming County.

In a short article in the Engineering and Mining Journal (Vol. XXVI, 1878, p. 439) there is a description of a 40,000-acre tract of timber along the Mahoopany Creek in Wyoming County in which the following statements are made: "This property has an especial interest as possessing an apparently unlimited amount of yellow ochre, which has been declared, after thorough test by experts, to be of excellent quality. The bed is said to have a thickness of about five feet, and it extends under a large area. The ocher bed rests directly upon a bed of rich 'clay band' carbonate of iron." The locality was not visited but presumably the so-called ocher bed is a series of yellow shales forming part of the Catskill formation.

CHAPTER VIII.

RED SHALES UTILIZED FOR PIGMENTS.

Red shales have been employed in the manufacture of paint in many places in the State although at present operations are being carried on in but three localities. The operations are not limited, however, by the distribution and amount of the shales but by the market for the product. Red shales occur in many of the geological formations but are especially well represented in the Martinsburg (Hudson River), Catskill, and Mauch Chunk of the Paleozoic Era, and the Brunswick shales of the Triassic Period.

The red coloring matter of these shales consists of ferric oxide which forms a coating about the individual grains and was no doubt present when the shales were deposited. In some places the iron content has been changed somewhat since deposition by the precipitation of more iron oxide while in other places there has been subsequent leaching by which some of the iron has been removed. However, since shales are relatively impervious to water, shale strata do not form good media for the passage of water and they are accordingly less apt to undergo subsequent changes in composition than are the more porous rocks.

Quarries of the J. Wilbur Company, Greenawald, Berks County.

The Martinsburg (Hudson River) shales are almost invariably black or gray in Northampton and Lehigh counties but to the west of Lehigh County layers of red and yellow shales are not infrequent. In the vicinity of Greenawald the J. Wilbur Company of Providence, Rhode Island, has been working some red shales of this formation since 1895 while during the years 1890 to 1895 similar material was worked near Lenhartsville.

The quarry where the greatest amount of material has been obtained lies about three-eighth mile east by south of the station at Greenawald. At that locality the shale bed suitable for use as a pigment includes a thickness of about 75 feet of fine grained dark brick red shales. The beds are tilted to the south at an angle of about 55°. The quarry was extended to the boundary lines of the property and excavated to a depth of 55 to 60 feet on the up-hill side of the opening.

The quarry now being operated lies near the top of a high hill about one-eighth mile east of the Greenawald station and has only recently been opened. Only about 600 tons had been shipped from this quarry at the time of our visit in September, 1910. The opening shows a thickness of 35 feet of good material while James S. Focht, the General Manager of the company, says that explorations have shown a thickness of 250 feet of workable material farther back in the hill. A double inclined track runs from the level of the railroad up to the quarry and the ore is taken down by gravity. A loaded car in descending pulls an empty car up to the workings.

The shale worked near Greenawald contains a great amount of fine-grained sericite sufficient to produce a soapy or talcose feeling when rubbed. On this account the material produced by the company is sold under the trade name of "talckene." The shale, especially in the recently abandoned quarry, is further of interest on account of the concentric discoloroation spots that are irregularly distributed throughout the material. The largest observed was about two inches in length and 1½ inches in width but most are less than half that size. In thickness they vary, but the discolored portions are seldom more than one-quarter inch thick. In the center of most there is a small rounded cavity but in a few there was seen to be a pyrite concretion the size of a small shot. The explanation is comparatively simple and involves two probable chemical reactions as follows:

$$FeS_2 + 7\,O + H_2O = FeSO_4 + H_2SO_4$$
$$2\,H_2SO_4 + Fe_2O_3 = 2\,FeSO_4 + H_2O + 2\,O$$

In the first place oxygenated water entering the shale comes in contact with the pyrite converting it into solouble ferrous sulphate and free sulphuric acid. The soluble salt is removed while the acid at once spreading outward unites with the ferric oxide coloring material of the shale forming another molecule of ferrous sulphate which in turn enters into soltuion and passes dwnward as the water percolates through the strata. The relatively impervious character of the shales interferes with the movement of the water across the beds hence the discolored portions do not have nearly as great an extent across the beds as within the ones that originally held the pyrite concretion. Except for the absence of the red coloring matter and the small cavity formerly occupied by the pyrite concretion the character of the discolored shale is not noticeably altered. The sericite and mud particles have not been affected and the white portions while doubtless somewhat less compact than originally, due to the removal of the iron oxide, seem to have practically the same physical composition.

Plate XXVII.—Quarry of Hudsondale Ocher Works, Hudsondale.

The following analysis of "talckene" is furnished by Mr. H. W. Rice, President of the J. Wilbur Company:

Organic and volatile matter, ...	4.297
Iron and aluminium oxides, ...	14.546
Silica and silicates, ...	81.157
	100.000

The shale is quarried and shipped to Philadelphia on the Philadelphia and Reading Railroad, a branch of which passes through Greenawald, where it is ground to a very fine powder. Its principal use is in the manufacture of oil cloth and linoleum.

The amount of material obtainable is practically unlimited and the cost of production low so that the output could easily be greatly increased if the market demanded it.

In the same vicinity the J. Wilbur Company is also quarrying a light yellow sericite shale which is likewise ground and used for linoleum. This deposit has been worked less than the red strata.

Quarry of the Atlas Mineral and Machinery Company, Albany, Berks County.

About one-half mile south of Albany the Atlas Mineral and Machinery Company of Lincoln, New Jersey, has operated a quarry in the creek bluff from which considerable red sericite shale of the Martinsburg formation has been removed. The bluff is about 50 feet in height and the shale has a dip of about 60° E. Sericite is more abundant than in the shale at Greenawald and the concentric discolorations are absent. Much of the red iron oxide, however, has been removed and the shales are blotched irregularly. Percolating water carrying organic acids have probably been responsible for the removal of the coloring matter.

This quarry was last operated during the summer of 1908. The shale was shipped to the mill of the company at Lincoln, New Jersey, where it was ground.

Quarry of B. F. Ruth and Company, Greenawald, Berks County.

A short distance from Greenawald, B. F. Ruth and Company of Reading have also worked the red shales of the Martinsburg formation intermittently for several years. The general character of the shales and their occurrence are similar to those in the quarry of the J. Wilbur Company.

Hudsondale Ochre Works, Hudsondale, Carbon County.

The Hudsondale Ochre Works of Weatherly, R. F. D., work a quarry in the Mauch Chunk red shales about 1½ miles west of the small village of Hudsondale and operate a mill for grinding the product about one-quarter mile west of the village. The plant has been

operated at this place since 1888. It was started by Marshall L. Smith recently deceased, who had previously quarried yellow shales at Rockport and Penn Haven Junction. The business is now carried on by his widow.

The shale is brick red in color and contains considerable sericite, causing it to feel soapy to the touch. As this property is possessed to such a great degree by talc the finished product at this plant is marketed under the trade name of "talkene."

The section exposed in the quarry is as follows:

	Feet.
Red shale, decomposed and mixed with surface soil, ...	4
Red shale, rather soft, ...	12
Buff sand, ...	1 to 3
Red shale, hard and compact, does not break in thin laminae as does ordinary shale, ...	8 to 10
Lighter colored shale exposed in bottom of quarry, ...	
	29

The buff sand mentioned in the above section seems to occur in lenses as the quarry face shows rapid thinning and thickening of the stratum and it is said by the quarrymen to occur in pockets. The best material comes from the lower bed of red shale.

The dip of the beds varies considerably in short distances but in general the strata are gently inclined to the west.

A short siding allows the cars to be brought close to the quarry and the shale is taken to them by means of wheelbarrows. At the mill the material passes first through a rock crusher which reduces it to about three-eighths inch size. Thence it goes through an improvised rotary dryer about 15 feet in length. It is then ground in buhr mills and bolted through four 6-sided reels. The coarse particles, which do not pass through the fine meshes, are taken back to the buhr mills for regrinding. The finished product is sacked for shipment.

The output is about 4,000 tons annually, all of which goes to Philadelphia where it is utilized in the manufacture of linoleum and oil cloth.

Plant of Reno Brothers Paint Company, Pulaski, Lawrence County.

Reno Brothers Paint Company at Pulaski, Lawrence County, is one of the oldest operating companies in the State. The business was started by H. B. Reno in 1870 and has been continued to the present. The mine furnishing the material is located on the west side of the Shenango River valley about one-half mile north of Pulaski and less than one-half mile from the Mercer County line, while the mill for grinding the shale is located close to the Pulaski station of the Pennsylvania Railroad.

Plate XXVIII.—Grinding Mill of Hudsondale Ocher Works, Hudsondale.

Plate XXIX.—Grinding Mill of Reno Bros., Paint Co., Pulaski.

The shale is brick red in color and forms a part of the Pottsville formation. It was included in the Sharon sales of the Second Pennsylvania Geological Survey. The strata are practically horizontal and outcrop on the side of the valley a short distance from the top of the divide. The material used varies in thickness from 5 to 7 feet. Underlying it is blue shale while overlying it is a bed of compact gray sandstone which forms an excellent roof. The shales are worked through a tunnel driven into the side of the hill.

The shale is hauled by wagon to the mill at Pulaski where it is thrown upon a platform and exposed to the weather for some weeks or months in order to permit it to partially disintegrate, thus facilitating its grinding. It is later taken into the mill where it is first ground in a vertical Sturtevant rock crusher and then elevated to a bin on the ground floor above from whence it is fed into a Sturtevant grinding mill. The product is again elevated to the second floor where it is drawn by suction through a Raymond Impact Pulverizer by which the finest particles are separated from the coarser. The air separator divides the material into about two equal portions, the finer going into a bin while the coarser material returns to the grinder. If the product is to be shipped in the raw state it is packed in barrels or sacks from the bin. A considerable portion is calcined before being marketed and in that case is taken to a dryer. During the calcining process it is continually stirred in oroder to have the burning uniform throughout. From the dryer the product is passed through a flour bolting mill to remove any lumps that may have been formed during the burning.

The product of this plant is sold under the trade name of "Reno's French Umber Filler." The following analysis of the raw material is furnished by Mr. Charles E. Hull, the General Manager:

Combined water,	6.10
Silica,	57.26
Oxide of iron,	9.28
Alumina,	21.34
Lime,	0.25
Magnesia,	0.16
Titanic acid,	0.94
Alkalies,	3.29
Manganese,	0.00
Sulphuric anhydride,	0.02
Phosphoric acid,	0.10
	98.74

From the above analysis it can be readily seen that the product is not an umber and the reason for so designating it is not known.

The product is used as a filler for many kinds of articles. It is used on both metal and wood to fill the small pores and pits and thus make a smooth surface on which other paint is later applied. It is used as a base in many prepared fillers and is frequently mixed with white lead. Most of it is sold to steel and iron manufacturers, particularly locomotive, safe, and structural steel makers, and is shipped to many points throughout this country as well as to Canada, Mexico, and France.

Plant of Pulaski Umber Company, Pulaski, Lawrence County.

The Pulaski Umber Company operates a mine on property adjoining that of Reno Brothers Paint Company and is working the same bed of red shale. The mill where the shale is ground is located on the east side of Shenango River within the town of Pulaski. This plant is not operated continuously and the mill is, at present, in need of repairs.

The finishing process is somewhat different from that of the plant previously described. After weathering, exposed to the rain and sun, the shale is passed through a rock crusher and then goes to a ball mill which is said to hold 5 tons of steel balls. From the ball mill it goes to a reel fitted with 8-mesh wire screens and thence to flour reels with No. 17 silk bolting cloth. It is then bagged or sent to a dryer if the burned product is desired. The burned material is again bolted to eliminate any lumps. At each stage of screening and bolting the coarse material is returned to the ball mill.

Plant of Pilmas Paint Company, Tioga County.

The Pilmas Paint Company of Elmira, New York, has mined some red shale about 3 miles north of East Charleston, in Tioga County, and have ground it about 1 mile east of Crooked Creek P. O. (Holliday Station on the New York Central Railroad).

The rock is a light red shale lying near the base of the Catskill (Cattaraugus) formation. Only about 100 tons have been dug, most of which have been used for experimental purposes and none has been dug for several years.

Mr. W. E. Mandeville, President of the Company, has furnished the following analysis of the material:

Silica,	75.52
Alumina,	9.85
Iron oxide,	4.95
Lime,	1.27
Magnesia,	1.29
Potassium oxide,	2.02
Sodium oxide,	2.22
Loss on ignition,	3.14
	100.26

Red Shales of Wyoming County.

The Catskill formation, which has an extensive distribution in the northeastern portion of the State, contains many beds of red shales. At one time these were worked by the Scranton Paint Company near Factoryville, Wyoming County. The ore was first roasted and then ground in oil. The product was satisfactory and the supply of shale ample, but the market for such material being limited and competition keen, the operations were discontinued several years ago.

Red Shales of Somerset County.

Along Paint Creek in the extreme northern portion of Somerset County, red shale and red clay of the Coal Measures (Allegheny formation), were dug for use as a paint several years ago. The material was only used locally for painting barns and other buildings and operations have long since ceased. The strata utilized are said to have been from 1 to 3 feet in thickness. That portion of the shales which had been disintegrated to form clay was used rather than the unaltered beds.

Red Shales of Armstrong County.

The following statements occur in the Geological Report of Armstrong County* by W. G. Platt:

"Variegated shales ..... have been exposed on the property of Mr. J. E. Shoemaker, at Centreville (now Meredith), by whom they have been worked to a small extent for the purpose of making from it a rough paint, similar to that used in many other localities in the coal regions where deposits of clay have been saturated with solutions of iron. Some of the shales in question have a purple color, while some are dark red according to the amount of iron in them and the degree of oxidation which has taken place. They are of little value, excepting as the paint may find favor in the neighborhood."

*Sec. Geol. Surv. of Pa. H 5, p. 164, 1880.

The strata to which the above statements refer evidently form a part of the Conemaugh formation.

In describing the region of Putneyville the same author (pp. 154-155) says: "A deposit of ferruginous clay from which a rough brownish paint was made by mixing the pulverized clay with oil, occurs along the roadside below the horizon of the Freeport Upper Coal. The deposit could be utilized for painting by the farmers in the country round about, but otherwise it has no value." The materials in question form a part of the Allegheny formation.

Red Clay, Venango County.

In Report O 3 of the Second Pennsylvania Geological Survey (p. 71) mention is made of a specimen of mineral paint collected on "Small's farm, just north of Pleasantville, Venango county." Mr. E. D. Dodge states that an attempt was made to use some red clay occurring at that locality for painting by mixing it with oil but with indifferent success.

CHAPTER IX.

IRON ORES USED IN THE MANUFACTURE OF PAINTS.

The iron ores composed of the ferric oxides, limonite and hematite, have been used in many places throughout Pennsylvania and adjoining states by the manufacturers of metallic paint and mortar colors. At present there are no iron ore mines, other than those described in another chapter under the head of ochers, that are being operated for paint within the State, but occasional references occur in the literature, however, of such uses in the past.

Clinton Iron Ore.

The Clinton or fossil iron ores occur in the Clinton formation of the Silurian period and are distributed through the counties of the central part of the State. At present the Clinton ores of Pennsylvania are not being worked but a considerable amount of New York Clinton iron ores is being used by Pennsylvania paint manufacturers. The Clinton hematite ore affords a superior base for the manufacture of metallic paint and mortar colors. For these purposes those ores are utilized in which there is a relatively high iron content as they are usually softer, more uniform, and possess a deeper color. The New York Clinton ores most extensively used for paint contain from 40 to 45 per cent. of iron.

E. V. d'Invilliers in describing a mine in the Danville fossil ore bed of the Clinton formation in Gregg Township, Union County* states that "all the loose outcrop soft fossil ore at this place was, during the summer of 1888, carted away to Mr. Tate's Paint Mill on the river below the mouth of White Deer Hole Creek, where it was burned in a fire-brick kiln to the extent of about 1½ tons per day; ground and packed in barrels and sold as brown paint in various markets, bringing high prices."

Hematite Ores of Perry County.

E. W. Claypole in his Report on Perry County† says: "A hard siliceous ore near or at the top of the Oriskany sandstone" occurs on the farms of Mr. H. Smith and Mr. Gibson near Gibson's Rock on Rock Hill, Carroll Township. "The Oriskany betrays itself almost exactly at the turn in the road, and following it is a bed of red iron ochre from which many tons have been taken and ground for paint,

*Sec. Geol. Surv. of Pa. F 3, p. 85. 1891.
†Sec. Geol. Surv. of Pa., F 2, pp. 101 and 161, 1885.

which is said to be of good quality. The seam varies from one to three feet in thickness and has been followed along the outcrop for about 80 or 100 feet, but no attempt is now made to mine it."

Lesley in the Summary Final Report (p. 1184) says: "In describing the Oriskany sandstone the fact was mentioned that in a few places in Perry County a bed of iron ore overlies it, which has been dug for the manufacture of paint in one or two places; corresponding to the paint ore of Rocky Ridge at the Lehigh Water Gap." Such a correlation as suggested seems probable although it has not been tested.

Hematite Ores of Tioga County.

H. D. Rogers* in describing the Vergent (Chemung) group, makes the following statements: "The hills one mile S. of Mansfield, which are about 200 feet high, are composed of flaggy, calcareous, and sandy shale of a greyish and olive tint, abounding in fossils. These are chiefly in the calcareous courses or partings, but their casts are also abundant in the sandy beds and in the red layers of the ore. This ore is opened about 50 feet below the top of the hill; the diggings display sandy and argillaceous calcareous slate 5 feet thick. Beneath this is a band of red sandstone ore 6 inches thick, underlaid by 6 feet of shale and slate. Below this lies the principal ore-bed, estimated to be from 12 to 15 inches thick. It is a deep purplish brown, and has been ground by the proprietor, Mr. Boxby, (Bixby?) for use as a paint. Some of it is oolitic, or seedy, resembling some kinds of the Surgent (Clinton) fossiliferous ore."

Sherwood in 1878† describes the same locality as follows: "It (the iron ore) has also been opened on the opposite side of the river, on Bixby's Hill, where considerable quantities have been obtained and ground into paint, of which it makes a good article for many purposes. An analysis by David McCreath is as follows:

Iron,	35.300
Sulphur,	.026
Phosphorous,	.215
Lime,	4.740
Insoluble residue,	28.845."

Hematite Ores of Berks County.

Red hematites occur sparingly in several places throughout Berks County associated with the other iron ores. Rogers** refers to "Peters Red Ochre Mine" located in the hills east of Reading, which seems to indicate that at one time hematite ore was dug for paint in that section. No other information concerning such a mine is available.

*Geology of Pennsylvania, Vol. I, p. 311, 1858.
†Sec. Geol. Surv. of Pa., G, p. 63. 1878.
**Geol. of Pa., Vol. 1, p. 200. 1858.

Limonite Ores of Monroe County.

I. C. White in his report on the "Geology of Pike and Monroe Counties"* describes deposits of limonite iron ore formerly used for paint. "*Brown Hematite* iron ore occurs in connection with these *black slates* (Marcellus) both at Kunkletown and Bonser's. At the former locality it was once burned and manufactured into *mineral paint,* on a small scale by Mr. Metzger.

"The ore seems to rest on the upper surface of the slates directly under the covering of soil and surface debris. It would probably average 40 per cent. of metallic iron, and should a considerable body of the ore be found on further exploration it would doubtless warrant mining, were any means of transportation at hand.

"A bed of this *Brown Hematite* is also seen along the road descending Little McMichael's Creek, a short distance from Sand Hill P. O. It was once hauled to Weissport in Carbon County, and used quite extensively in the manufacture of *mineral paint* for barns, bridges, freight cars, etc. It rests upon the upper surface of the slates, just like that at Bonser's and Kunkletown, and hence it has all accumulated since the present topography was channelled out, because the *ore* does not lie in a flat bog but on a considerable slope where the drainage must have been free, except the arresting power of a clayey soil."

*Sec. Geol. Surv. of Pa., G 6, pp. 114-115. 1882.

CHAPTER X.

MINOR SUBSTANCES USED IN THE MANUFACTURE OF PAINT.

Besides the substances already described in preceding chapters there are several other kinds of materials that occur in Pennsylvania that are occasionally used in the manufacture of paint. All of these are used for other purposes mainly, consequently, a full discussion of them would be out of place in this report. For that reason their discussion is brief and general.

Graphite.

Associated with the gneisses, schists, and marbles of the Piedmont Plateau in the southeastern portion of the State are many strata containing graphite. In a few places the graphite is present in large enough amounts and the flakes are of sufficient size to warrant their mining. For many years graphite has been mined in Chester County in a belt extending from Kimberton to Byers (Uwchland P. O.) Several mines in that section are at present in operation while others have recently been closed. The mines have frequently experienced difficulty in the separation of the graphite from its associated minerals, especially mica, and for that reason have been less profitable than they otherwise would have been. The graphite is abundant and the flake is good.

Besides the Chester County localities graphite has been mined in several places in Bucks, Berks, and Lehigh counties although all operations ceased many years ago. The ore, in general, contains a lower percentage of graphite in these places than in Chester County.

The graphite found in Pennsylvania has a variety of uses, one of which is in the manufacture of graphite paint which is extensively used for structural steel painting.

The graphite deposits and the graphite industries of the State will be fully described in a later report now in progress of preparation.

Soapstone and Talc.

Soapstone (steatite) and talc occur in several places within the State in the crystalline rocks of the Piedmont Plateau closely associated with serpentine from which it has in most cases been formed. Much of the soapstone is ground and used in various ways, including its use in the manufacture of mineral paint. In two localities within the State soapstone is now being quarried for such a purpose. C. K. Williams and Company of Easton quarry and grind

soapstone occurring in Chestnut Hill, lying just north of Easton, while the Atlas Mineral and Machinery Company of Lincoln, N. J., is operating a quarry along the Schuylkill River in Montgomery County, about 1½ miles northeast of Gladwyne. In all probability the latter quarry will soon be abandoned. The Chestnut Hill deposit, which extends across the Delaware River in New Jersey, has been described in considerable detail by F. B. Peck in the Annual Report of the State Geologist of New Jersey for 1904 (pp. 163-185) and a revision by the same author is now in process of preparation.

Barite.

Barite, or barytes, is used to a considerable extent for mixing with white lead in the manufacture of white paint. A certain amount of it is desirable but when an excess is used it is merely an adulterant. In Pennsylvania barite has been reported from several localities but in most places it is of interest only from a mineralogical standpoint. However, in Fulton and Franklin counties it has been found in several places in large enough quantities to justify mining on a small scale. These localities have been briefly described in several reports* of the United States and Pennsylvania geological surveys.

Chromite.

Chromite, or chromic iron ore, occurs in several places in the crystalline rocks of the southeastern portion of the State. Its main use is in the manufacture of chrome yellow, orange, and green pigments, although it has had several other uses.

In Lancaster, Delaware, and Chester counties mines were at one time extensively worked but, at present, all have been abandoned. The mines furnished some very fine ore which, although usually occurring in small masss, were occasionally found in much larger bodies. In the U. S. National Museum there is one block of fairly pure ore from Lancaster County which weighs about 1,000 pounds. The chromite ore was found associated with the basic pyroxenites and peridotites or the serpentines and talc resulting from their alteration.

The chromite deposits of Pennsylvania have been briefly described in several reports† issued by the State:

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*Geol. of Pa., Vol. 1, pp. 258, 414, 1858.
Sec. Geol. Surv. of Pa., CCC, p. 262, 1880.
" " " " " T 2, p. 304, 1882.
U. S. Geol. Surv., Bull. 225, pp. 515-516, 1904.
†Geol. of Pa., Vol. 1, pp. 170-171, 1858.
Sec. Geol. Surv. of Pa., B, pp. 39-43, 1875.
" " " " " C 3, pp. 176-178, 1880.
" " " " " C 4, pp. 91-94, 1883.
" " " " " C 5, pp 35, 55, 60, 1885.

Pyrite.

Pyrite has been used to a limited extent in the manufacture of paint. By roasting it a deep red pigment is obtained.

In Pennsylvania pyrite occurs in small quantities in almsot all the systems of rocks but seldom in bodies large enough to justify the equipment of mines for its extraction. It has been mined in the vicinity of Emaus but operations have long since ceased.

The only instance known to the writer where Pennsylvania pyrite has been used in the manufacture of paint is in Mercer County where some pyrite obtained from the Coal Measures was utilized by the Oriental Paint Company of Jamestown.*

Clay and Kaolin.

Several varieties of clay and also kaolin are used in small amounts in the manufacture of mixed paints. Clays suitable for such purposes are widely distributed throughout the State while kaolin occurs in the belt of crystalline rocks in the southeastern portion only. In Delaware and Chester counties kaolin has long been worked. These deposits were described by Lesley and Ashburner† in 1886 and by Hopkins** in 1900 while the latter also described the clays of western Pennsylvania in 1898.††

Although Pennsylvania ranks high in its production of clay yet the amount used in the manufacture of paint is so small that a fuller discussion of the clay deposits would be out of order in this report.

*Sec. Geol. Surv. of Pa., MM, p. 374, 1879.
†Sec. Geol. Surv. of Pa., An. Rep. 1885, pp. 571-614, 1886.
**Clays of Southeastern Pa., An. Rep. State College for 1898-99, 76 pp., 1900.
††Clays of Western Pa., An. Rep. State College for 1897, 183 pp., 1898.

CHAPTER XI.

CONDITION OF THE MINERAL PIGMENT INDUSTRY.

For many years Pennyslvania has been the leading state in the production of ocher and metallic paint, yet the deposits are by no means exhausted. The industry is in a prosperous condition although there is no immediate prospect for any considerable expansion nor is there any demand for it. Foreign materials still have the preference over local pigments and it is not probable that conditions will be materially changed within the near future. France supplies the greater portion of the ocher used for paint. Italy sends us practically all the sienna used in this country, while the best grade of umber is obtained from Turkey.

Of the various products described in this report, with the exception of umber, sienna, and some of the minor constituents, all are found in great quantities. The ocher deposits are seldom large but on the exhaustion of the material in one locality more can be found nearby. Great quantities of ocher from the limonite ore when the mines were operated for iron ore occur in many places but have been uesd in only a few localities. These alone are sufficient to supply the market demand for low grade ocher for many years to come.

The carbonate of iron (metallic paint) ores of the Lehigh Gap region are in greater danger of exhaustion although at the present rate of production there seems to be little danger of the supply of ore above the level of the Lehigh River failing within the next 25 years while the amount at a lower level is entirely unknown. At present all the mines in that section are drained by tunnels and the deepening of the mines would finally result in pumping which would materially increase the cost.

Shales such as are now employed within the State exist in almost unlimited quantities although tests would be necessary to determine their fitness. The proper color is the greatest desideratum but of almost equal importance is the amount of oil required to make a satisfactory paint. It has been found by experience that certain shales require an unusually large amount of oil, hence they are of less value.

For the operation of a mineral pigment deposit in Pennsylvania a relatively small amount of capital is required. The necessary outlay seldom exceeds a few thousand dollars while in some cases a few hundred dollars will suffice.

The mineral pigments mined in the State are almost all refined before being shipped to other states. The material sent elsewhere goes as raw unwashed material; as refined, burned or unburned dry colors; or in the form of mixed paints. Figures are not available for the proportions of each class but the number of Pennsylvania manufacturers of mixed paints, linoleum, and oilcloth who use local material in large amounts seem to indicate that the greater part of the State's production is consumed locally. Dry refined colors are shipped to many distant points, however, and a small amount of material leaves the State in the form in which it is mined.

LIST OF MINERAL PIGMENT PRODUCERS OF PENNSYLVANIA.

Ochers.

	Location of Mine.
*Bear Bros., Breinigsville, Pa.,	Breinigsville
Erwin, Henry, & Sons, Bethlehem, Pa.,	Topton, Easton
Long, Dr. Wilson P., Weatherly, Pa.,	Hancock
Prince Metallic Paint Co.,	Trexlertown
Reitnauer, John D., Alburtis, R. F. D., Pa.,	Seisholtzville
Sampson, Amandus K. S., Easton, Pa.,	Easton
Victor Mining Co., 140 Maiden Lane, New York, Alburtis, Pa.,	Wescosville
Williams, C. K., & Co., Easton, Pa.,	Fleetwood, Reading

Umber.

Williams, C. K., & Co., Easton, Pa.,	Bethlehem

Sienna.

Lance, Mrs. John P., 122 North Fourth St., Reading, Pa.,	Reading

Carbonate of Iron (Metallic Paint) Ores.

Freyman, William G., & Co., Mauch Chunk, Pa.,	Little Gap
Prince Manufacturing Co., 2 and 4 Cliff St., New York,	Hazard
Prince Metallic Paint Co., Allentown, Pa.,	Millport

Black Shales.

Keystone Paint and Filler Co., Muncy, Pa.,	Muncy
Myers, Mrs. John, Allenwood, R. F. D., Pa.,	Fritz Station
Penn Keystone Co., Williamsport, Pa.,	Antes Fort

Yellow Shales.

Luzerne Ocher Mfg. Co., White Haven, Pa.,	Moosehead
Wilbur, Jr., Co., 12 Dudley St., Providence, R. I.,	Greenawald

*No production during 1910.

Red Shales.

	Location of Mine.
*Atlas Mineral and Machinery Co., Lincoln, N. J.,	Albany
Hudsondale Ocher Works, Weatherly, R. F. D., Pa.,	Hudsondale
*Pilmas Paint Co., 207 Realty Building, Elmira, N. Y.,	Charleston
Pulaski Umber Co., Pulaski, Pa.,	Pulaski
Reno Bros. Paint Co., Pulaski, Pa.,	Pulaski
Wilbur, J., Co., 12 Dudley St., Providence, R. I.,	Greenawald

Soapstone and Talc.

Atlas Mineral and Machine Co., Lincoln, N. J.,	Gladwyne
Williams, C. K., & Co., Easton, Pa.,	Easton

STATISTICS.

The statistics of production of the mineral pigments of Pennsylvania are presented in the following table for the years 1905 to 1910 inclusive. The pre-eminence of the State in this class of materials is apparent when compared with the total output of the entire United States during the same years. Although natural mineral pigments are produced in about 15 different states, about one-half the entire production comes from Pennsylvania.

*No production during 1910.

Production of Natural Mineral Pigments in Pennsylvania, and the United States, 1905-1910.a

Pigment.	1905.		1906.		1907.		1908.		1909.		1910.		Total 1905–1910.	
	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.	Quantity. Short tons.	Value.
Pennsylvania.														
Ocher,	5,464	$62,825	5,774	$67,029	5,430	$65,491	6,963	$63,035	4,137	$45,472	3,642	$32,254	31,410	$336,106
Umber and sienna,b	499	10,040	441	8,944	489	9,870	1,142	30,225	1,253	33,150	1,015	26,700	4,839	118,929
Metallic paint,	5,266	80,210	7,319	95,483	6,950	91,900	5,281	69,799	8,120	105,683	8,063	91,714	40,999	534,789
Slate and shale,	10,400	70,399	11,569	75,475	11,822	84,690	10,224	76,099	11,592	85,645	12,660	81,139	68,267	473,447
Mortor color.c	1,050	11,500	995	11,400	1,330	13,490	640	6,800	2,662	31,416	2,711	33,752	9,388	108,358
Total,	22,679	$234,974	26,098	$258,331	26,021	$265,441	24,250	$245,958	27,764	$301,366	28,091	$265,559	154,903	$1,571,629
United States.														
Ocher,	11,077	$116,816	12,659	$135,834	14,354	$153,417	14,696	$140,439	12,458	$125,349	11,711	$112,445	76,955	$784,300
Umber and sienna,b	619	14,840	542	12,994	545	11,304	1,212	30,705	1,276	33,472	1,015	26,700	5,209	130,015
Metallic paint,	15,274	160,862	16,610	189,413	15,048	181,693	14,022	156,694	20,722	201,905	29,422	184,869	111,098	1,075,436
Slate and shale,	13,396	93,067	14,239	92,915	12,702	92,130	12,617	93,181	14.944	98,176	16,515	96,001	84,413	565,470
Mortor colors,	9,399	104,430	8,909	94,920	9,490	97,719	7,856	72,881	10.820	108,126	9,960	107,780	56,434	585,856
Total,	49,765	$490,015	52,959	$526,076	52,139	$536,263	50,403	$493,900	60,220	$567,028	68,623	$527,795	334,109	$3,141,077

a—Statistics furnished by the United States Geological Survey.
b—Figures for umber and sienna combined to avoid disclosure of individual production.
c=Includes considerable material from other states.

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